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PACIFIC SCIENCE

A QUARTERLY DEVOTED TO THE BIOLOGICAL AND PHYSICAL SCIENCES OF THE PACIFIC REGION

IN THIS ISSUE: Wood — *Diatoms in the Ocean Deeps* • Emery and Cox — *Beachrock in the Hawaiian Islands* • Tokioka — *A New* Fritillaria • Cowper — *New Gadiform Fish from Australia* • China and Slater — *New Subfamily of Hemiptera* • Barnes and Barnes — *Biology of* Balanus • Desikachary — *Observations on* Liagora • Bary — *Mysidacea and Euphausiacea from New Zealand* • Ito — *New Copepods from Japan* • News Notes • Index

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(Continued on inside back cover)

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Diatoms in the Ocean Deeps

E. J. Ferguson Wood[1]

The conception of a rain of diatoms from the plankton to the ocean deeps is, at first thought, a reasonable one. Further thought, however, makes it appear extremely unlikely. Because diatoms occur in swarms, particularly in certain areas of the oceans, it seems to have been assumed that they descend more or less vertically to form diatomaceous ooze. In fact, in deeper waters, we could expect them to become widely dispersed, especially as their form is such as to retard vertical movement. Further, there is the question of the gradient of silica concentration with depth, and the effect of pressure thereon. Harvey (1945) states that the silica content of seawater, in general, has been found to increase with depth, and that it is probably in true rather than colloidal solution. This suggests that the diatom tests are dissolved as they fall through the water after the death of the cell.

Wiseman and Hendey (1953) found large numbers of the diatom *Ethmodiscus rex* (Rattray) Hendey in material collected from the Mariana Trench by H.M.S. "Challenger" in 1951. These authors speculate regarding the origin of the tests, pointing out that *E. rex* is rare in the plankton, and that, "there is no indication that the species is found living in the waters immediately over the deposit itself." They do not consider the possibility that the diatom is autochthonous.

During a microscopic examination of a mud sample from the Weber Deep (depth, 7,400 m.) in a search for living bacteria, I observed a number of benthic types of diatom frustules. The sample studied was collected by Claude E. ZoBell and Richard Y. Morita during the "Galathea" expedition in 1951, and has since been kept in a pressure bomb at 10,500 p.s.i. and 10°C.

Microscopic Observations

Some of the frustules seen appeared to contain protoplasmic material (Fig. 1), as did some *Globigerina* and *Nummulites* which were also observed. Some showed dense spherical bodies, usually four in number, which could have been microspores (Figs. 2, 3). The larger *Coscinodiscus* forms appear to have burst, as did the form shown in Figure 3, probably owing to the rapid release of pressure when the bomb was opened. The smaller *Coscinodiscus* remained intact for the most part.

The cells from some preserved material were stained with various aniline dyes and took up the stain. When stained with acridine orange and viewed under fluorescent light they fluoresced orange-red, whereas the empty frustules did not fluoresce. Hence it may be concluded that the stained cells did contain protoplasm. It is impossible that both cell and protoplasm could have been preserved intact during a slow descent of 7,400 metres from the photic zone, so the evidence that these forms are autochthonous is very strong. Further, many of the frustules of all the species

[1] Scripps Institution of Oceanography, La Jolla, California, U.S.A. and Marine Biological Laboratory, Cronulla, Australia. Manuscript received October 21, 1955.

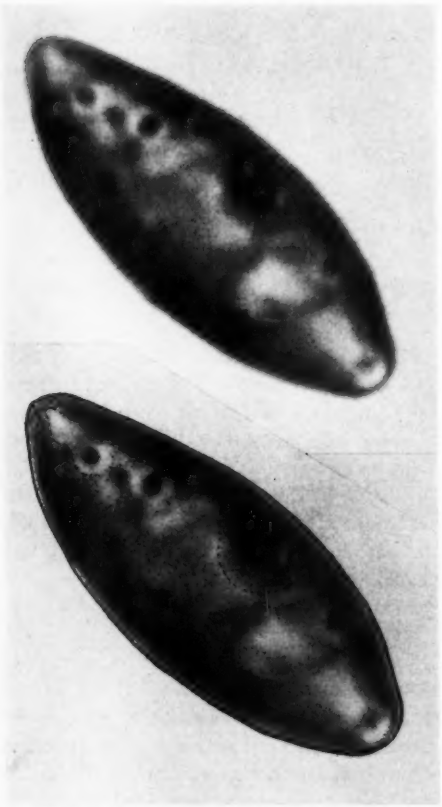

FIG. 1. A naviculoid diatom from the Weber Deep. It contained a brown pigment, vaculoes, fat(?) globules, and nucleus but no chloroplasts. Lower figure retouched. (Phase contrast.)

observed were intact, and appeared quite fresh and uneroded. No planktonic forms were observed, nor were there even fragments of such species as *Rhizosolenia*, *Chaetoceras*, etc., as one would expect from the "rain" theory.

Table 1 lists all of the "Galathea" stations from which bottom material was examined. The samples were first examined directly and again after digestion with hydrochloric acid. Cell contents were seen in material from stations 463 and 492.

In Table 2 the species of diatoms observed and the station from which they came are listed.

The samples all contained numerous sponge spicules, and the presence of these and of the sessile forms *Synedra* and *Melosira* suggest that these diatoms may be epiphytic on the sponges. It is interesting to note also that all, or nearly all, the forms mentioned in Table 2 are found as fossils, and that *Melosira granulata* and *Cocconeis pendiculus* are not recorded from seawater. Since the flora associated with the ocean deeps is unique, it would appear that we are dealing with a separate biocoenosis. Studies made by ZoBell (1952) on the bacterial flora contained in the same samples confirm this.

EXPERIMENTAL

If the diatoms are autochthonous, as I suggest, they must be living saprophytically. Recently, Lewin (1953) has described experiments in which diatoms were grown heterotrophically in the dark in a medium containing tryptone and glucose. She points out in her paper that if the diatom cultures are not pure, the bacteria outgrow the diatoms. Accordingly I obtained two cultures of her heterotrophic strains in order to test their growth under pressure, at the same time endeavouring to grow some diatoms in culture from the "Galathea" material.

All the cultures were made in the following medium—an adaptation of that suggested by Lewin:

Solution a	K_2HPO_4	0.02 g.
	$MgSO_4$, $7H_2O$	0.02 g.
	$CaNO_3$, $4H_2O$	0.01 g.
	Glucose	5 g.
	Tryptone	1 g.
	Distilled water	100 ml.
Solution b	Seawater	900 ml.
	Agar (if required)	15 g.

The solutions were sterilized separately and after cooling to about 50°C. were combined.

The cultures, placed in small tubes so as to leave an airspace above, were closed with neoprene stoppers, placed in pressure bombs (ZoBell and Oppenheimer, 1950) and pressurized at 1, 100, 200, and 500 atmospheres.

Fig. 2. *Coscinodiscus marginatus* Ehr. from Weber Deep showing dense spherical bodies (microspores?).

In addition, the "Galathea" material was pressurized at 1,000 atmospheres. In the case of the pure cultures, suspensions were made in a small amount of the medium, and 0.1 ml. was pipetted into the small tubes which were then partially filled with the medium. After 14 days, the bombs were opened, the tubes centrifuged for 15 minutes at 4,000 r.p.m., the density of the deposit estimated, and the material examined microscopically. The following observations were made.

1,000 Atmospheres Pressure

"Galathea" material only. Some *Coscinodiscus marginatus* with cell material.

500 Atmospheres Pressure

"Galathea" mud. *Coscinodiscus* containing refractile bodies and a long straight rod-like body.

Culture 6 M. Cells square with 2 to 4 green, somewhat refractile bodies, deposit density rated as 1. (Fig. 4*a*.)

Culture 13 M. Cells oval to rounded, with refractile bodies; greenish to brownish. Deposit density, 1.

200 Atmospheres Pressure

"Galathea" mud. *Coscinodiscus* with refractile bodies, and cell material between the valves.

Culture 6 M. Cells square to oblong, with greenish-brown chloroplasts. Notably heavy sediment of cells; density, 2.

Culture 13 M. Cells oval, more elongate than at 500 atmospheres. Chloroplasts brown, nucleus evident; vacuoles frequent, with particles either in Brownian movement or rotating. Cells frequently paired as though they had divided recently.

100 Atmospheres Pressure

"Galathea" mud. *Coscinodiscus* observed apparently containing cellular material; other empty tests seen.

Culture 6 M. Cells normal in appearance, i.e., like original culture. Growth heavier than at 1 atmosphere. Density, 2.

Fig. 3. Naviculoid diatom from Weber Deep which appears to have burst at side and end. (Phase contrast.)

Culture 13 M. Paired cells frequent. Cells oval, frequently with a vacuole at one end containing particles in motion. Fair growth, more than at 1 atmosphere. Density, 1–2.

1 Atmosphere Pressure

Culture 6 M. Cells similar in form to those of parent culture; poor growth. Density, 1. (Fig. 4*b*.)

Culture 13 M. Cells more oval than at high pressure. Density slightly less than at 100 atmospheres.

There appears to have been more growth at 100 and possibly at 200 atmospheres than at 1 atmosphere, but little or no growth at 500 atmospheres. Cells were more square in 6 M and circular (13 M) at high pressures.

Material from these cultures was transferred to agar slopes. Cultures 6 M grew on this medium from 1, 100, 200, and 500 atmospheres, and there was some evidence of growth of 13 M at 500 atmospheres, but the other cultures were overgrown by bacteria.

The experimental evidence suggests that diatoms taken from atmospheric pressure may grow heterotrophically or remain viable at pressures up to 500 atmospheres, and this supports the possibility of the growth of

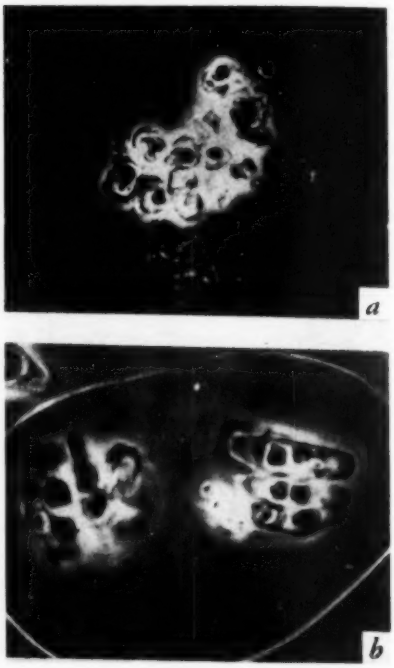

FIG. 4. Diatoms of culture 6M: *a*, Grown at 500 atmospheres pressure; *b*, grown at atmospheric pressure in bomb. (Phase contrast.)

TABLE 1

SPECIMENS OF BOTTOM MATERIAL EXAMINED COLLECTED BY THE "GALATHEA"

STATION	LOCATION		WATER DEPTH (Metres)	DATE COLLECTED	DEEP	DIATOMS PRESENT
	Lat.	Long.				
418	10°20′N	126°30′E	10,387	15/ 7/51	Mindanao	....
422	10°49′N	126°01′E	2,010	24/ 7/51	Mindanao	+
440	10°25′N	126°40′E	10,610	14/ 8/51	Mindanao	+
463	10°16′N	109°51′E	7,214	3/ 9/51	Sunda	+
492	5°31′S	131°01′E	7,445	20/ 9/51	Weber	+
496	5°36′S	131°06′E	7,465	23/ 9/51	Weber	+
497	.....	.....	9,000+	24/ 9/51	Weber	+
517	6°31′S	153°58′E	9,020	11/10/51	Solomons	+
517 ?	6°31′S	153°58′E	9,255	13/10/51	Solomons	....
608	44°31′S	167°50′E	390	18/ 1/52	Milford Sound	+
645	35°16′S	178°40′E	8,515–8,425	13/ 2/52	Kermadec	....
650	32°20′S	176°54′W	6,794	16/ 2/52	Kermadec	....
658	35°51′S	178°31′W	7,837–7,901	21/ 2/52	Kermadec	+
677	38°38′S	175°53′W	6,370	4/ 3/52	Kermadec–Tonga	....
678	28°30′S	175°53′W	9,437	4–5/ 3/52	Kermadec–Tonga	....
678 (water)	28°30′S	175°53′W	9,335	4–5/ 3/52	Kermadec–Tonga	....
686	20°53′S	175°31′W	10,080	11/ 3/52	Kermadec–Tonga	....

TABLE 2

DIATOMS OBSERVED IN MUD COLLECTED BY THE "GALATHEA" AND STATIONS AT WHICH THEY WERE TAKEN

SPECIES	STATION NUMBER
Coscinodiscus marginatus Ehr.	422, 463, 492, 496, 497, 517, 517?, 608
Coscinodiscus pacificus (Grun) Rattray	440
Synedra tenera W. Sm.	463
Melosira granulata (Ehr.) Ralfs	463
M. moniliformis Mueller	497
Navicula	
Nitzschia panduriformis Greg.	463
Cocconeis pendiculus Ehr.	463
Diploneis crabro Ehr.	463
Pinnularia dactylis Ehr.	440
Ethmodiscus rex (fragts)	440
Coscinodiscus centralis Ehr.	497
Trachyneis aspera (Ehr.) Cleve	463
Pleurosigma normani Ralfs	497

abyssal diatoms at this and higher pressures.

There is a great deal to support the theory enunciated in this paper that the diatoms found in abyssal mud samples may be autochthonous, and, so far, no indication that the flora found in the ocean deeps is allochthonous. Even in shallow estuarine muds planktonic forms are rare or absent except for the heavily silicified *Coscinodiscus*, *Biddulphia*, etc.

ACKNOWLEDGMENTS

I wish to thank Dr. Claude E. ZoBell, and the Rockefeller Foundation, for providing the opportunity for me to visit the Scripps Institution of Oceanography and undertake this work, Dr. Joyce Lewin for cultures of her strains of heterotrophic diatoms, Dr. Carl H. Oppenheimer for taking the photomicrographs, and Mr. L. H. Crosby of the Marine Biological Laboratory, Cronulla, for the specific determination of the diatoms.

REFERENCES

HARVEY, H. W. 1945. *Recent advances in the chemistry and biology of seawater*. vii + 164 pp. Cambridge University Press, Cambridge.

LEWIN, JOYCE C. 1953. Heterotrophy in diatoms. *Jour. Gen. Microbiol.* 9: 305.

WISEMAN, J. D. H., and N. I. HENDEY. 1953. The significance and diatom content of a deep sea floor sample from the neighbourhood of the greatest oceanic depth. *Deep-sea Res.* 1: 47.

ZOBELL, C. E. 1952. Bacterial life at the bottom of the Philippine Trench. *Science* 115: 507.

ZOBELL, C. E., and C. H. OPPENHEIMER. 1950. Some effects of hydrostatic pressure on the multiplication and morphology of marine bacteria. *Jour. Bact.* 60: 711.

Beachrock in the Hawaiian Islands[1]

K. O. Emery and Doak C. Cox[2]

Beachrock is a stratified calcareous sandstone (calcarenite) or conglomerate (calcirudite) occurring along many beaches that are composed of shells or other calcareous debris. It is common on beaches of islands that are bordered by coral reefs. Although many authors have described beachrock, few have agreed on its origin, either because critical data are lacking or because beachrock may form in several different ways. Preliminary studies of beachrock in the Marshall, Mariana, and Hawaiian Islands led the authors to believe that detailed mapping of beachrock in the Hawaiian Islands might show whether the distribution is related to abundance and composition of ground water or to other factors of the shore environment.

Examination of the shores of Oahu, Kauai, Molokai, and Maui during parts of June and July, 1954, was made possible by funds from Office of Naval Research contract NR 081–217.

Aid in field mapping, discussion, and critical reading of the manuscript was kindly given by Dr. Douglas Inman of Scripps Institution of Oceanography. Dr. Harold S. Palmer of Honolulu also read the manuscript and made some valuable suggestions.

GENERAL DESCRIPTION

Composition

The material that becomes cemented into beachrock is beach sand or gravel, chiefly calcareous. The sand ranges from fine to very coarse and, like other beach sands, is very well sorted (Table 1). Its generally coarse grain size, excellent sorting, and high degree of rounding, make it very permeable. Tests on progressively coarser Oahu samples 14, 2, and 4 of Table 1, yielded permeabilities of 37, 120, and 570 darcys, respectively, values that are comparable with those of other beach sands.

The grains of sand consist chiefly of broken and worn pieces of calcareous parts of organisms, plus minor amounts of volcanic detritus. Volcanic detritus is unusually abundant in beachrock at Ohikilolo (about 2 miles south of Makua) on Oahu where it forms thin brown laminae, and at Kekaha on Kauai where it makes up the bulk of the beachrock as it does also of the unconsolidated sand. Generally, however, the volcanic detritus comprises only a small percentage of the total grains. A summary of the composition of 33 samples of loose beach sand is given in Table 1. The source organisms were identified by shape and mineralogy of the grains: Foraminifera and calcareous red algae being calcite; *Halimeda* and madreporarian coral being aragonite. The mineral form was determined by use of a solution of cobalt nitrate (Meigen's solution) which stains aragonite violet and does not affect calcite. Some pelecypod and gastropod shells consist of both aragonite and calcite; thus some become stained and others are not affected. Accordingly, shells were identified only by remnants of flat or curved surfaces and occasionally by traces of decorative colors. These methods are more fully described in a report on sediments of Guam (Emery, in manuscript). Comparison of the composition of beach sands of the Hawaiian

[1] Contribution of Allan Hancock Foundation No. 167; contribution of Hawaii Marine Laboratory No. 76; published with the permission of the Director as paper No. 38 in the journal series of the Hawaiian Sugar Planters' Association. Manuscript received February 3, 1956.

[2] Department of Geology, University of Southern California and Experiment Station, Hawaiian Sugar Planters' Association, respectively.

Islands, Guam, and Bikini (Emery, Tracey, and Ladd, 1954: 38) shows the same major constituents in all the sands, but some differences in their relative proportions (Table 1). In the Hawaiian beach sands the most abundant constituent appears to be fragments of pelecypod and gastropod shells. Pieces of calcitic debris believed to be from calcareous red algae are next, followed closely by tests of Foraminifera, mainly *Amphistegina* with occasional *Marginopora*. Coral is relatively rare, and *Halimeda* debris was not found. The remaining material, called "fine debris" was too minute to permit visual identification of source organisms. Examination of polished sections of beachrock after similar staining showed the same assemblage of organisms, but percentage determinations were hampered by the presence of much calcitic cementing material.

Gravels that become cemented into beach conglomerate consist of wave-worn coral heads, large mollusk shells, pieces of basalt (Fig. 1), and reworked slabs of older beachrock (Fig. 2). Among the few places where beachrock contains volcanic gravels are areas near Kaena Point, Hauula, and Kapoho Point on Oahu, and Laau Point on Molokai. Silt and clay may also be present in beachrock

FIG. 1. Beachrock 3½ miles east of Kaena Point, Oahu. Lower layers contain many cobbles of volcanic rock.

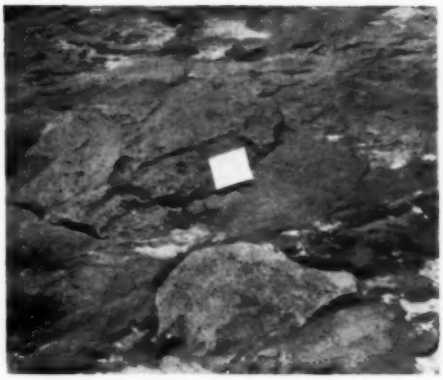

FIG. 2. Beachrock at Keaau, Oahu, containing reworked slabs of older beachrock.

but are most conspicuous as distinct interbedded layers of alluvium or soil as at Keaau on Oahu (Fig. 3).

Near Laniloa Point and Kapoho Point on Oahu, and Nohili on Kauai, eolianite overlies beachrock near the high tide level. It may be distinguished by its finer grain size, steeper dip, and generally poorer cementation.

Cementation

The cementing material that binds sand into beachrock has been described by Ginsburg (1953), Emery, Tracey, and Ladd (1954: 43–45, 148, 149, pls. 22, 50, 52, 58), Illing (1954: 48, 70), and Ranson (1955) as consisting of calcite with some aragonite. Cementing material in beachrock from the Hawaiian Islands is similar to that described elsewhere, except that no aragonite was found. Failure of any of the pore fillings to become stained with Meigen solution indicates that all of it is calcite. Dr. Heinz Lowenstam of California Institute of Technology kindly confirmed the determination using a different stain.

Thin sections of beachrock from the site of Figure 4 show that pores of the upper layers are more completely filled than those of the lower layers (Table 2). Rinds, 30 to 60 μ thick and consisting of clear acicular calcite crystals about 4 μ thick, surround all the grains in the

loose slab, surround less than 1 per cent of the grains in Layer G, and are absent in lower layers. The rest of the pore filling is brown calcite having randomly oriented grains that are more or less equidimensional and about 2 μ in diameter. If the pore filling found in the loose slab has passed through the stages of cementation represented by the lower layers, A to C, the rind of acicular calcite must be a secondary recrystallization feature.

The more complete filling of pores near the surface correlates with the common observation that beachrock is much harder at its exposed surface than at a depth of only an inch or two. An evaluation of the degree of cementation of beachrock at depth was made in the bay just west of Kahuku Point on Oahu. In this area, beachrock is especially well exposed (Fig. 4) because of retreat of the beach, probably due largely to sand removal by man. At least seven distinct layers of beachrock are present, some of which contain slabs reworked from older layers. Inspection of the exposed portions showed that the lower layers are less well cemented than the upper ones. The hardness of each layer was determined semiquantitatively by measuring the depth that a drill rod could be driven by 50 blows of a 16-pound sledge hammer (Fig. 5). Each layer was found to be slightly harder at its top surface than at depth. A deep hole, starting in Layer G, showed variations in driving rate correlative with the variations measured at the surface for the respective layers. The lesser resistance to driving found at depth also correlates with layers of poor cementation as judged from outcropping edges. Increased resistance at the bottom of the hole was probably due to entry into underlying reef rock. Similar results were obtained in another deep hole started in Layer C. Decrease in cementation at depth is also

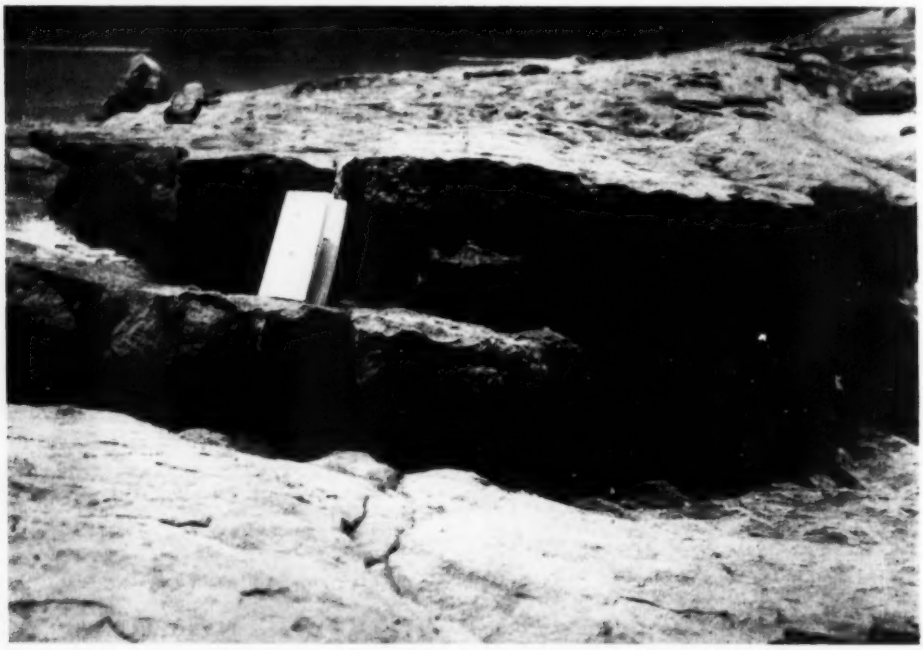

FIG. 3. Whaleback of beachrock at Keaau, Oahu, with two interbedded layers of red alluvium.

FIG. 4. Layered beachrock dipping seaward at west side of small bay west of Kahuku Point, Oahu. Note reef rock on left against which beachrock abuts. Site of measurements diagrammed in Figure 5 is at left center.

well shown in the walls of a large drainage ditch cut through 5 feet of beachrock at Waieli on Kauai.

The characteristically poorer cementation at depth leads to ease of undercutting and movement of large slabs by waves. A slab near Kahuku Point on Oahu weighing probably 15 tons may have been overturned by the tsunami of 1946 (Fig. 6). Solution basins have just begun to form on the exposed bottom. Other areas having numerous loose slabs are Barbers Point, the beach a mile south of Waianae, and Makua on Oahu; Nohili on Kauai; and Hale o Lono on Molokai. At Nohili, erosion of soft material from beneath beachrock has allowed large slabs to slump to a position several feet below low tide level. The loose slabs are generally much harder than beachrock *in situ*, probably because cementation has proceeded from both top and bottom. When struck with a hammer the most firmly cemented slabs ring like gongs.

Surface

The surface of poorly cemented beachrock is rough, granular, and friable. That of well-cemented beachrock, however, is hard and becomes modified by at least four separate processes: polishing and film formation, discoloration by boring blue-green algae, biochemical solution, and abrasion.

Polishing of the surface is fairly common. In part, it is produced by continual washing of sheets of calcareous sand across the rock. It is present, therefore, chiefly where thin patchy sands overlie the beachrock. Cross sections of truncated shells, coral and other recognizable organic debris show on the surface. Polishing is supplemented by deposition of a film of very thinly laminated aragonite on the surface, which, as at Bikini (Emery, Tracey, and Ladd, 1954: 46, pls. 42, 43), fluoresces a bright reddish-orange under ultraviolet light. The film is especially well shown on beachrock at Nanakuli and on basalt at Mauna Lahilahi (about 1½ miles southeast of Makaha) on Oahu, on beachrock at Nohili on Kauai, and on beachrock at Kepuhi on Molokai. Especially at Nanakuli (Fig. 7) and Nohili the film appears to constitute a form of case-hardening that resists the development

of solution basins. Some of the loose sands, such as Oahu sample 4 and Maui sample 1 of Table 1, are also highly polished and contain many grains which fluoresce. Illing (1954: 69) has noted similarly polished and coated sand grains on Bahaman beaches.

The second process that modifies the surface of hard beachrock is a darkening that is produced by activities of boring blue-green algae. In general the rock surface is a dull medium-to-dark gray, but at a few sites it is bright blue. Among the latter sites are Kawela Bay, Barbers Point, and Nanakuli on Oahu, and Kepuhi on Molokai. A piece of coral embedded in beachrock at Barbers Point was examined by Dr. Maxwell S. Doty of the University of Hawaii, who found *Entophysalis crustacea* and *Galothrix* living at the surface. For ¼ inch beneath the surface there was a succession of colored bands that Doty ascribed to natural chromatography of plant pigments and their decomposition products. The bands and their probable composition are as follows, from the surface inward:

blue—phycocynin
pink—phycoerythrin
clear
yellow—a carotinoid
green (thickest)—chlorophyll

Small pink or green spots at the sides of

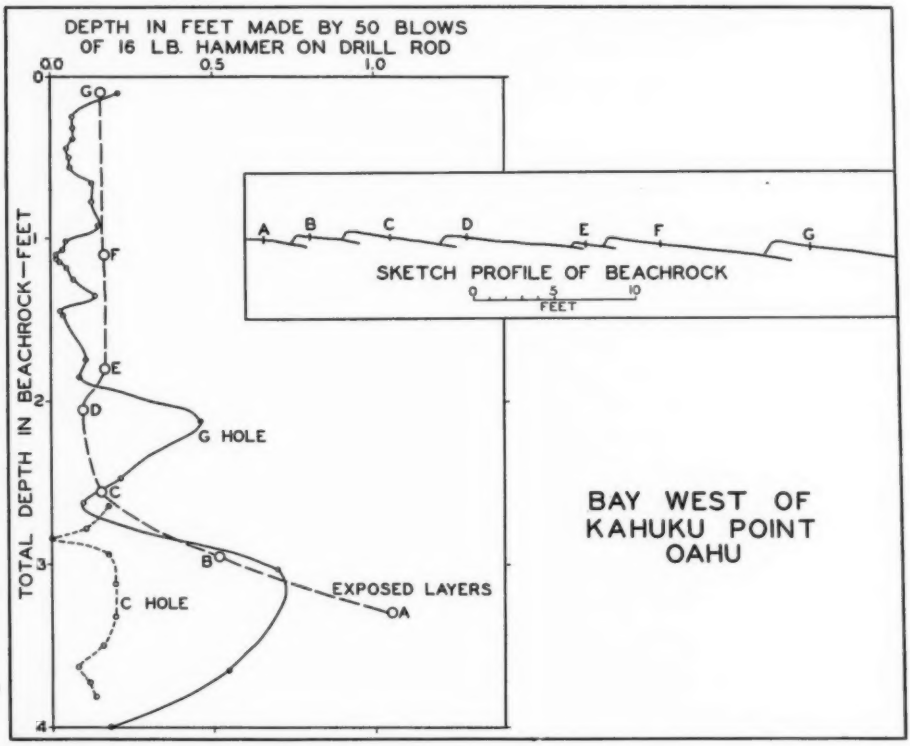

FIG. 5. Semiquantitative measurement of rock hardness, or degree of cementation, as determined by depth to which a drill rod could be driven by 50 blows of a sledge hammer. Line with long dashes shows measurements for exposed edges of layers. Solid line shows variation of hardness with depth in a hole driven vertically through all layers. Line with short dashes shows variation in a hole through three lowest layers.

TABLE 1
CHARACTERISTICS OF BEACH SANDS

LOCATION	MEDIAN DIAMETER MM.	SORTING COEFFICIENT	RESIDUE INSOLUBLE IN DILUTE HCl PER CENT BY WEIGHT	COMPOSITION OF CALCAREOUS PORTION (Per cent by Weight)					
				Foraminifera	Shells	Fine debris	Halimeda debris	Coral	Calcareous algae
Oahu									
1. 5 mi. E Kaena Pt.	0.56	1.16	30	15	30	0	0	25	30
2. 1½ mi. W Mokuleia	0.98	1.29	5	25	35	0	0	10	30
3. Waimea Bay	0.73	1.33	5	40	40	0	0	5	15
4. 1 mi. E Waimea	2.10	1.50	0	2	55	0	0	5	38
5. ½ mi. S Laniloa Pt.	0.38	1.44	5	5	40	20	0	5	30
6. E side Kualoa Pt.	0.56	1.32	2	10	35	0	0	5	50
7. N Kaneohe Bay	0.18	1.69	99						
8. ¼ mi. N Kapoho Pt.	0.67	1.31	8	35	35	0	0	5	25
9. Kailua	0.58	1.54	1	15	30	0	0	5	50
10. 1 mi. S Kailua	0.22	1.22	45	10	25	50	0	5	10
11. Waimanalo	0.31	1.13	1	20	40	10	0	10	20
12. Hanauma Bay (E Koko Head)	0.63	1.47	98						
13. 2 mi. NW Koko Head	0.34	1.33	2	10	35	10	0	5	40
14. S side Diamond Head	0.62	1.29	30	10	30	0	0	20	40
15. W Ewa Beach	0.83	1.73	5	15	35	0	0	5	45
16. ½ mi. N Nanakuli	0.58	1.45	2	30	25	0	0	5	40
17. 1 mi. S Makaha	0.55	1.70	1	60	25	0	0	0	15
Kauai									
1. Haena	1.30		5	60	20	0	0	0	20
2. Hanalei Bay	0.20	1.53	80						
3. Kapaa	0.58	1.36	1	1	20	0	0	20	59
4. 3 mi. SE Waieli	0.28	1.43	0	5	15	0	0	25	55
5. Waieli	0.22	1.35	0	5	40	0	0	20	35
6. 4 mi. NE Nohili	0.40	1.30	10	5	15	0	0	35	45
Molokai									
1. 2 mi. S Kepuhi	0.45	1.19	5	50	20	0	0	0	30
2. Halawa	0.29	1.22	70	40	45	0	0	5	10
3. 5 mi. SW Cape Halawa	0.18	1.21	97						
4. 4 mi. E Kaunakakai	0.37	1.23	90	10	45	0	0	5	40
5. 1 mi. W Kaunakakai	0.23	1.61	75	10	65	0	0	10	15
Maui									
1. 2 mi. S Makena	0.41	1.50	1	60	20	5	0	0	15
2. 5 mi. S Kihei	0.19	1.16	10	10	40	40	0	0	10
3. 5 mi. SE Lahaina	0.23	1.20	95						
4. 2 mi. N Honokowai	0.76	1.49	40	50	35	0	0	0	15
5. Lower Paia	1.10		5	5	20	10	0	25	40
Hawaiian Islands average (33)	0.54	1.38	29	21	33	5	0	9	32
Guam average (11)	0.45	1.41	9	8	29	2	6	36	20
Bikini average (30)	0.87	1.51	0	26	9	4	2	28	31

FIG. 6. Large overturned slab of beachrock ½ mile east of Kahuku Point, Oahu, estimated to weigh about 15 tons. Solution basins have begun to form on the now exposed bottom.

boulders and in some solution basins are evidently the result of natural removal of the original, outer, colored layers. A brief description of these algae and their effect in coloring the surface of limestone has been given by Newhouse (1954). As pointed out by Cloud (1952: 28, 29) blue-green algae also invade the surface layer of loose beach sand, where they make a thin green layer and provide a weak form of cementation.

The remaining two surface processes, solution and abrasion, develop larger erosional features that have been well described by Wentworth (1944). Most common are basins

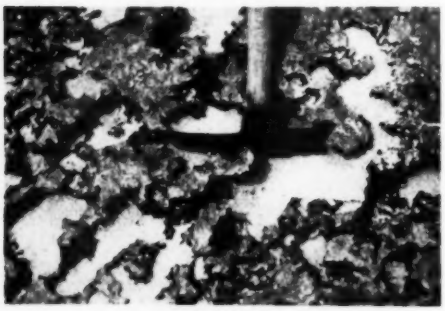

FIG. 7. Solution basins in beachrock having a case-hardened surface formed by deposition of a thin film of calcium carbonate at a place ½ mile north of Nanakuli, Oahu.

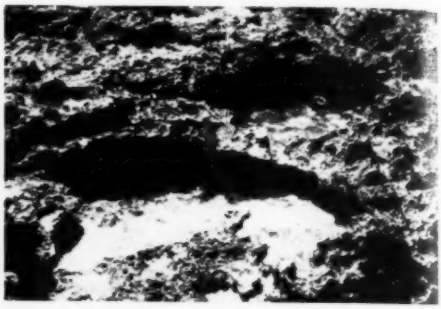

FIG. 8. Solution basins in reef rock ½ mile north of Mauna Lahilahi, Oahu. The reef rock surface is seen to be typically rougher than that of beachrock.

produced through solution of calcium carbonate by sea water trapped in pools (Fig. 8). This process is a complicated one and, as it is described rather fully by Revelle and Emery (in press), it will not be discussed here except to point out that solution basins are best developed and have sharp serrated edges in well-cemented beachrock (Layer G of Fig. 5, for example), they have rounded edges in moderately cemented beachrock (Layer F), and they do not exist in poorly cemented beachrock (Layers A to E). Their absence in poorly cemented beachrock is the result of high permeability that allows the pools to drain before much solution can occur. Solution also has produced water-level terraces that usually are divided by narrow low ridges into a series of rimmed pools (Fig. 9). These terraces and rimmed pools are common in reef rock of all the islands (Wentworth, 1939) but were noted in beachrock only at Nohili on Kauai, and at Hale o Lono on Molokai.

In contrast to the roughly circular form of solution basins, there are channels that are elongate and extend down the slope of the beachrock. These features have smooth, straight sides, and they quite evidently are produced by mechanical erosion along joints or other discontinuities through movement of sand or pebbles by wash of waves. Intermediate between the solution basins and the channels are potholes produced through me-

chanical abrasion by one or more cobbles that happen to become trapped in solution basins or other depressions in the beachrock.

Relationship to Beaches

In the Hawaiian Islands the maximum range of the tide is about 3 feet. Waves wash the beaches to a level ordinarily 2 or 3 feet higher than high tide. Little of the beachrock extends higher than the top of the wave-washed zone, but in several places it extends as much as 3 feet below low tide (west of Kahuku Point and at Hauula on Oahu; Nohili on Kauai; and Spreckelsville and Honokowai on Maui).

Most beachrock occurs on sandy beaches, usually with the same strike and dip as the layers of loose sand (Fig. 4). No beachrock was found at the ends of rocky points that project seaward between beaches, probably because of lack of sand.

In several places the beachrock, though at about the same height as the beach, has a different position in plan. The most conspicuous difference is shown by spits of beachrock that curve seaward away from the present beach, such as one at a point 1½ miles west of Mokuleia on Oahu (Fig. 10), and near Honokowai and at five places between Kahului and lower Paia on Maui.

FIG. 9. Rimmed terraces in beachrock at Nohili, Kauai. Note narrow anastomosing ridges that separate the pools of different levels. These consist of beachrock, showing that the rimmed terraces are erosional rather than built up by deposition. Beachrock extends several feet, at least, below low water.

FIG. 10. Curved spit of beachrock near Mokuleia, Oahu, showing that considerable retreat of beach sand in background has occurred since the time of cementation of the beachrock.

More common are "whalebacks," or anticline-like masses of beachrock located immediately off the beaches. In these the strike parallels the beach, but the layers dip seaward and landward on opposite sides. Such whalebacks were observed at Paumalu, south of Laniloa Point, Keaau (Fig. 3), Makua, and 4 miles east of Kaena Point on Oahu. An intermediate feature, massive seaward-dipping beachrock that forms a sort of offshore bar, occurs at Waieli and Nohili (Fig. 11) on Kauai. In many of these and other localities, the beach has obviously undergone large recent losses of sand owing either to natural causes, or to mining by man, or to both. Retreat of some beaches is also shown by recent undercutting of trees, by exposure of very soft beachrock at the back of beaches, and by historical records.

Along the coast of Oahu from 1 to 3 miles east of Kaena and at Diamond Head, beachrock is present but present-day beaches are either absent or are very small. East of Kaena, at Waimea, and on both sides of the point 2 miles south of Makaha, small patches of beachrock lie atop reef rock that has been raised 5 to 7 feet above mid-tide. These patches have sufficient horizontal extent to differentiate them from sands that have accumulated in small pockets of reefs as shown in the raised algal reefs at Waimea on Oahu. South of Laniloa Point and elsewhere, massive

FIG. 11. Bar-like ridge of seaward-dipping beachrock just beyond beach of loose sand at Nohili, Kauai.

beachrock overlies reef rock and reaches as much as 10 feet above mid-tide. At Kaena Point a Pleistocene shoreline 95 feet above sea level (Stearns, 1935) is marked both by reef rock and by about 13 feet of beachrock. Raised reef rock capped by beachrock was observed on none of the other three islands.

In summary, the position and attitude of most beachrock is closely accordant with present beaches, but some beachrock is discordant with present beaches owing to retreat of beaches, or to coastal elevation or submergence after the beachrock was formed.

DISTRIBUTION AND HYDROLOGY

General

The shores of Oahu were examined more thoroughly than those of Kauai, Molokai, and Maui, because beachrock is more abundant and the shores are more easily accessible. After experience had shown the rarity of beachrock at the ends of rocky points, most of the effort was spent on sandy bays between points. Altogether about 190 stations were made along the shores of Oahu, 100 on Kauai, 40 on Molokai, and 70 on Maui. Hawaii was not examined because beaches are rare and consist mostly of noncalcareous sand. Although Midway Island was not visited, Mr. J. A. Neff of the United States Fish and Wildlife Service (personal communication) reported the presence of slabby rock on Eastern Island that probably is beachrock. The results of the survey, based on measurements from the plottings on topographic maps, are presented in Table 3. Simplified plots for each of the four islands are given in Figures 12, 14, 16, and 17. Where no indication of beachrock or beach sand is given, the area was either not visited or was considered an impossible site for beachrock because of the absence of a sand beach.

It seems advantageous to describe very briefly the hydrology of the Hawaiian Islands because of the hypothesis that the development of beachrock is in some way controlled by the outflow of ground water through beaches. The hydrology of the four islands on which beachrock was studied is generalized in Figure 18.

The Hawaiian Islands consist of volcanic mountains built predominantly of basaltic lava flows and extending to heights of from 1,000 to 13,000 feet above sea level. Rainfall on these mountains is heavily influenced by the degree to which the moisture-laden winds, particularly the northeast trades, are forced upwards in their passage over or around them.

TABLE 2

COMPOSITION OF THIN-SECTIONS OF BEACHROCK SHOWN IN FIGURE 4

	PERCENTAGE OF AREA OF THIN-SECTION			PERCENTAGE OF ORIGINAL PORE AREA NOW FILLED
	Grains	Pore filling	Empty pores	
Loose slab	66	26	8	76
Layer G	57	33	10	77
Layer C	59	23	18	56
Layer B	56	15	29	35
Layer A	63	11	26	31

TABLE 3
GEOGRAPHICAL DISTRIBUTION OF BEACHROCK IN HAWAII

COAST	TOTAL MILES OF COAST	MILES OF SANDY BEACH EXAMINED	MILES OF BEACHROCK	PERCENTAGE BEACHROCK OF SANDY BEACH EXAMINED	PERCENTAGE BEACHROCK OF TOTAL COAST
Oahu					
Mokuleia to Paumalu	13.6	4.0	0.1	2	
Paumalu to Makahoa Pt.	10.4	6.0	4.9	82	
Makahoa Pt. to Mokapu Pen.	33.6	20.8	1.0	5	
Mokapu Peninsula	11.2	1.7	1.5	88	
Kapoho Pt. to Waikiki Beach	31.4	16.5	1.3	8	
Waikiki Beach to Pearl Harbor	19.5	0.0	0.0?	0	
Pearl Harbor to Mokuleia	42.5	24.0	12.0	50	
Total	162.2	72.0	20.8	29	13
Kauai					
3 miles NE Nohili to Kealia	47.4	10.2	2.6	25	
Kealia to Waimea	46.5	12.4	2.6	21	
Waimea to 3 miles NE Nohili	16.6	13.0	2.6	20	
Total	110.5	35.6	7.8	22	7
Molokai					
4 miles E Hale o Lono to Kepuhi	15.2	7.5	4.8	64	
Kepuhi to Cape Halawa	50.9	0.0	0.0?	0	
Cape Halawa to 4 miles E Hale o Lono	38.2	9.0	0.0	0	
Total	104.3	16.5	4.8	29	5
Maui					
Maliko Bay to Makena	84.2	0.0	0.0?	0	
Makena to Lahaina	31.5	10.5	0.0	0	
Lahaina to Kahului	34.0	7.3	1.6	22	
Kahului to Maliko Bay	11.1	6.6	1.7	26	
Total	160.9	24.4	3.3	14	2
Grand Total	537.9	148.5	36.7	25	7

In areas of maximum rainfall, located on the windward slopes of the higher mountains and at the crests of the lower mountains, the mean annual rainfall is commonly in excess of 200 inches per year. On the leeward slopes the rainfall is generally much less than on the windward slopes, and on the lower parts of leeward slopes the mean annual rainfall may be less than 20 inches per year. The wide geographic variation in rainfall creates wide variations in both surface-water and ground-water resources.

There is surface runoff from all except the youngest terrains formed by fresh porous lava flows. The courses of the streams are, however, so steep and short that the runoff alone creates flashy and, in the low rainfall areas, infrequent flows. However, many streams have cut valleys sufficiently deep to tap ground-water bodies that are perched on layers of comparatively low permeability interbedded in the generally highly pervious lava flows or are impounded between intrusive bodies in the central areas of the volcanoes, and have thereby developed perennial flows from springs. Much of the portion of the rainfall that infiltrates the surface does not reappear in high-level springs, but descends

FIG. 12. Distribution of beachrock on Oahu.

to sea level in the lavas where it accumulates to form lenses of fresh water floating on the denser salt water penetrating from the sea. The thickness and freshness of these lenses depends in part on the amount of infiltration they receive and in part on the ease with which the water in them can drain seaward. Where the lavas crop out at the coast line there is generally easy outflow, and the lenses are thin. Particularly on the older islands, however, there may be extensive coastal plains underlain by prisms of sediments, partly coral and other limestones of generally high permeability, but also partly muddy sediments whose permeability is much lower than that of the lavas. Such sedimentary prisms constitute barriers restricting or diverting the ground-water outflow and causing the freshwater lenses to be thicker in the bedrock behind such coastal plains.

Oahu

The northwestern coast of Oahu, from Mokuleia to Paumalu, is low, and two of the island's largest rivers enter at Waialua and Waimea Bays. Ground water stands comparatively high in the bedrock lavas behind the coast, except in a stretch a couple of miles each side of Waimea Bay, its height indicating that its drainage seaward is restricted by the sediments that make up the coastal plain. Springs create swamps on parts of the plain, and some of the drainage of these swamps may take place diffusely through the beaches, though the largest outflows are probably by way of the rivers and a few springs at or below sea level. Beachrock was found at only one locality (Fig. 12), not near a spring, where it dips seaward in the wave-washed zone.

The northern shore, backed by a wide limestone plain from Paumalu to Makahoa Point,

is characterized by an almost continuous strip of beachrock interrupted by a few sand-free projecting points. Within the bays, beachrock forms seaward-dipping strata as much as 4 feet thick atop reef rock (Fig. 4), though locally the beachrock is so thin that reef rock projects through it. The contact between reef rock and beachrock is commonly near the mid-tide level (Fig. 13). In most of this area the beachrock is in the wave-washed zone; but just east of Kahuku Point it rests on reef rock reaching to 5 feet above mid-tide, and just west of Kahuku Point it extends a foot or two below low tide. As it does farther west, the ground water stands high in the bedrock lavas back of this northern shore, and again leakage from the bedrock creates swamps and ponds in the limestone plain. The points of seaward drainage from these swamps are not known, but there are no conspicuous springs at or above sea level. No perennial streams reach the shore in this stretch of the coast.

Eastward from Makahoa Point the coastal plain narrows and is broken by stretches where bedrock lavas crop out at sea level. At such places there must be outflow of ground water, and at a few places there are visible springs at or just above sea level. The mountain rainfall increases eastward, the valleys are more deeply incised, and a number of perennial streams reach the shore between Makahoa Point and the base of Mokapu Peninsula.

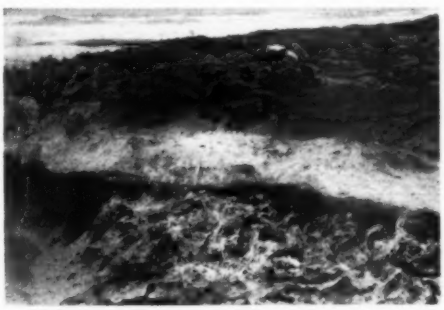

FIG. 13. Contact of beachrock atop reef rock near mid-tide level at a place one mile east of Kahuku Point, Oahu.

This shore contains little beachrock. Most of that which is present occurs between Laniloa Point and Hauula, where it forms thin seaward-dipping beds in the wave-washed zone except in the middle of the area where it rises from below mid-tide to 8 feet above mid-tide and is overlain by hard eolianite. About 1 mile south of Laniloa Point poorly cemented eolianite occurs at the base of a 10-foot cliff cut in dune sand. Beachrock was not found within Kaneohe Bay, an area of dilute sea water with many fish ponds along the shore. Islands within the bay are free of beachrock, perhaps because of the absence of loose sand, and, in the case of Coconut Island, because of artificial shores.

The Mokapu Peninsula consists of a core of late, relatively impervious, volcanic rocks and a surrounding limestone plain. The rainfall is low and there are no streams and probably very little ground water. Along shores on the eastern side of the peninsula there are extensive and massive beds of beachrock dipping seaward. Most of the beds are in the wave-washed zone, but near Ulupau Head some of the beachrock atop reef rock reaches to 10 feet above mid-tide. At Kapoho Point the reef rock is overlain by eolianite that has been truncated and drilled by potholes that later became filled by alluvium.

Over the eastern end of Oahu the rainfall decreases again, and no perennial streams drain to the coast east of Waimanalo and Honolulu. The permeability of even the bedrock is low in Kailua and Waimanalo on the windward side of the island, and although ground water stands relatively high in places, the amount of flow is probably not great. In the Honolulu area there are well-developed ground-water bodies in the bedrock whose seaward drainage is so restricted by coastal-plain sediments that most of the outflow probably takes place laterally to the coast through a limestone plain east of Diamond Head, and to Pearl Harbor, at the head of which there are very large springs. Makapuu Head is a mass of bedrock lavas cut into

cliffs at sea level. The rainfall is so low there, however, that there is probably very little ground water. Koko Head and Diamond Head are pyroclastic cones of low permeability and probably contain negligible ground water.

The shore of the southeastern part of Oahu from Kapoho Point to Waikiki Beach is mostly free of beachrock, although sandy beaches are abundant. Beachrock occurs in small thin patches near Kailua, northwest of Makapuu Head, near Koko Head, and around Diamond Head. At Diamond Head it lies atop a tuff terrace and beneath talus and eolianite in areas now free of loose beach sand. In all the areas except the one northwest of Makapuu Head, the beachrock is in the wave-washed zone; at this one place, a 1-foot layer of beachrock atop reef rock reaches to 8 feet above mid-tide.

Between Waikiki and Barbers Point, leakage from well-developed ground-water bodies in the bedrock lavas and seepage from streams have created thin fresh-water lenses in, and swampy spots on, the surface of the coastal plain, much of which is composed of limestone. No notable shoreline springs are known, however, except the Pearl Harbor springs previously mentioned, which represent drainage direct from the bedrock. From Barbers Point northwest to Makaha the bedrock ground-water bodies are less well developed because the rainfall is much lower. There are still thin lenses of ground water in the coastal-plain sediments as far as Makaha, at least, but again no notable shoreline springs are known. No perennial streams reach the shore. The Kaena Point area at the western end of the island is very dry.

Shores between Waikiki Beach and the entrance of Pearl Harbor are so altered by man that they were not investigated. Beginning at the entrance of Pearl Harbor and extending around Barbers Point and Kaena Point to Mokuleia, the coast is dominated by beachrock except at projecting sand-free points. Between the entrance of Pearl Harbor and Barbers Point beachrock alternates with loose sand, with a general westerly increase in abundance of beachrock. Where present, the beachrock is restricted to the wave-washed zone. The 4-mile stretch of coast northwest of Barbers Point and the 5-mile section southeast of Kaena Point were not visited because of the lack of roads. Lava reaches the shore most of the way in the latter stretch (Wentworth, 1938: 8). Along most of the rest of the Waianae shore, beachrock is almost continuous except on the projecting points. The beachrock is almost equally divided between massive beds in the wave-washed zone (Fig. 2) and thin patches atop reef rock to heights of 5 to 8 feet above mid-tide. At Keaau it is interbedded with alluvium (Fig. 3). About half of the shore of abundant beachrock is backed by a wide limestone plain (Fig. 12), but in the northern part, from Keaau to Makua, only the beach separates the lavas from the sea.

Kauai

The island of Kauai has had a more complex structural history than the other Hawaiian Islands. As a consequence, the permeability of its rocks is in general lower and the amount of ground water smaller in relation to surface water.

The western half of the northern coast, from 3 miles northeast of Nohili nearly to Haena Point, consists of cliffs cut into bedrock lavas and is inaccessible except by foot or boat. Sand beaches are rare and no beachrock has been found.

Most of the rest of the northern coast, the eastern coast, and the southern coast to Waimea, consist of gentle slopes or low cliffs cut in relatively late lavas of generally low permeability. Numerous perennial streams reach the sea, and beaches at their mouths are common. In addition, there is a narrow coastal plain extending with minor breaks for about 5 miles south from Kapaa. Southwest of Nawiliwili Bay for 5 miles the coast consists of cliffs similar to those of the northwestern

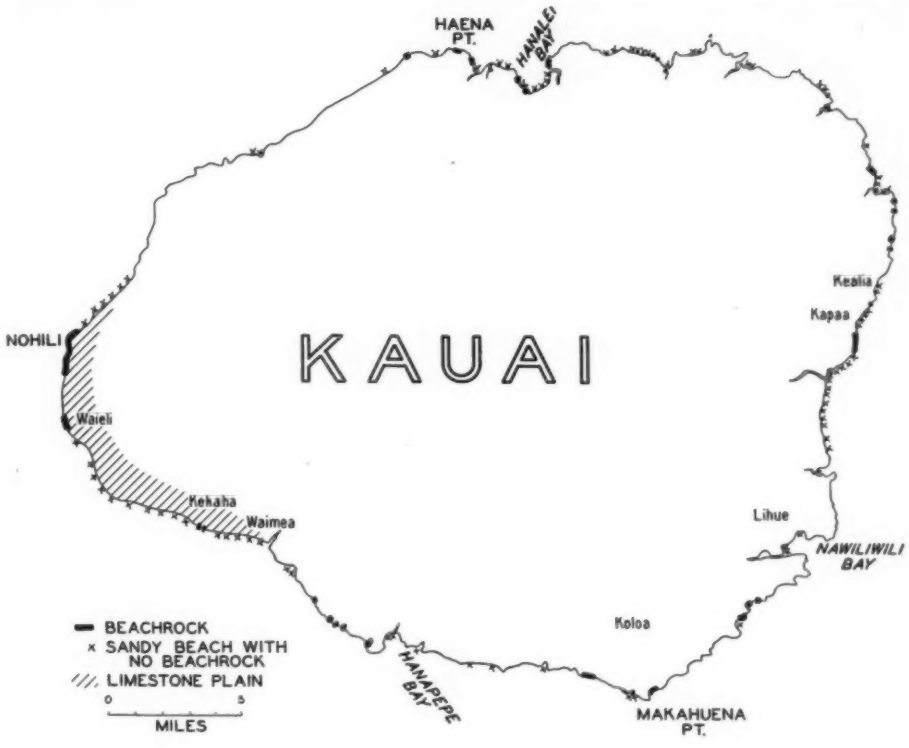

FIG. 14. Distribution of beachrock on Kauai.

coast. Beachrock is present in many small patches along these coasts, none more than 0.3 mile long (Fig. 14) and all consisting of thin seaward-dipping beds in the wave-washed zone. About a half dozen occurrences between Haena and Kealia are at the mouths of small to moderately large streams, in contrast with the absence of beachrock in such places on Oahu.

The western coast, between Waimea and a point 3 miles northeast of Nohili, is backed by a limestone plain that reaches a width of 2 miles. The surface of the plain was once largely covered by a swamp fed by intermittent streams and by leakage of ground water from the bedrock lavas in cliffs back of the plain, but the swamp has been artificially drained. Along the seaward margin is a wide high sandy beach locally backed by dunes. A local fisherman reported that the northernmost part of the beach has become considerably wider in the past few years and in this area no beachrock is exposed. The escape of fresh ground water through the beach sand is notable 3 miles northeast of Nohili, where the coastal plain pinches so that the beach rests directly against the bedrock cliff. In the middle of the area, at Nohili, there is a 2-mile exposure of massive beachrock (Fig. 11) reaching about 4 feet above mid-tide and at least 3 feet and possibly 8 feet below mid-tide. The uncertainty is due to slumping of large blocks of the beachrock due to the erosion of some undetermined softer material

FIG. 15. Beachrock at Nohili, Kauai, showing solution basins having rounded and smoothed surfaces believed to indicate modification of ordinary sharp-edged solution basins during a period of burial under loose beach sand followed by exhumation.

underlying it. The slumped blocks range up to 30 by 15 by 5 feet. A shorter exposure of beachrock at Waieli has been transected by a drainage ditch that reveals progressive decrease of cementation of the beachrock at depth. Some of this beachrock has a rounded and smoothed surface (Fig. 15), unlike beachrock elsewhere which is undergoing active solution. This is presumed to indicate a former exposure of the beachrock followed by burial under thick sand, and finally exhumation by recent retreat of the beach. Judging from the massive nature of beachrock at both Nohili and Waieli, it seems likely that this entire section of the western coast is underlain by beachrock that now is exposed only where recent retreat of beach sand has occurred. Retreat of the beach has also exposed very poorly cemented beachrock and eolianite landward of the main mass of beachrock at Nohili.

Molokai

The eastern part of Molokai has a high rainfall, and is well drained by both surface streams and ground-water flow. Particularly along the southern coast a few miles south of Cape Halawa to a few miles west of Kaunakakai the escape of ground water at sea level is notable. The western part is very dry with no perennial streams and only brackish ground water.

Beachrock on Molokai is confined to the southwestern and western coasts, from a point 2 miles east of Hale o Lono to Kepuhi (Fig. 16). A 4-mile continuous exposure of beachrock, the longest seen in the islands, centers at Hale o Lono. Within the wave-washed zone and seaward-dipping, most of this beachrock is slabby and some of it has been quarried for building purposes. In the area north of Laau Point beachrock is slabby like that at Hale o Lono, but it reaches to 8 feet above mid-tide. The bay near Kepuhi contains some of the most massive beachrock seen in the islands, reaching from below mid-tide to 10 feet above it. The surface is highly polished

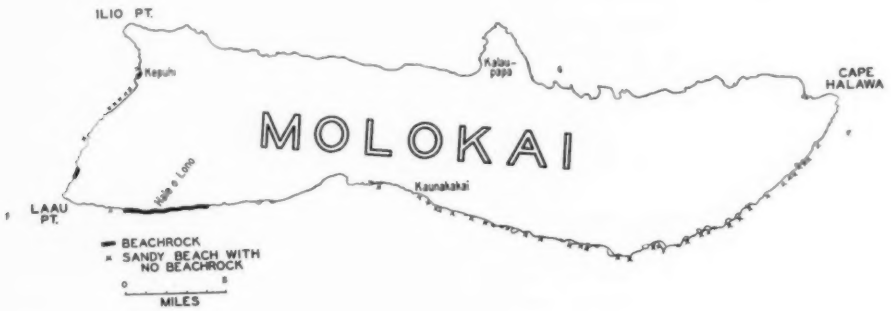

FIG. 16. Distribution of beachrock on Molokai.

FIG. 17. Distribution of beachrock on Maui.

and locally is discolored by blue-green algae. Elongate erosional channels are well developed.

From Kepuhi around Ilio Point to Cape Halawa, the coast is precipitous with only two sandy beaches. At one of these places, Kalaupapa, possible but uncertain beachrock was noted from a vantage point at the top of the high cliff about 2 miles away. This is believed to be the only possible site of beachrock along the entire northern coast of Molokai. The southern coast from Cape Halawa to Hale o Lono was examined closely without finding any trace of beachrock. Scattered along almost the entire shore are artificial fish ponds in which mullet and other brackish-water fish are cultivated. Muddy sediments have accumulated along the more protected parts of this shore. *Ulva*, or sea lettuce, is very abundant along the shores, forming local drifts about a foot thick.

Maui

Less beachrock was found on Maui than on any of the other islands examined, a total of 3.3 miles of shoreline length (Fig. 17). The absence of sand beaches around most of East Maui, from Maliko Bay to a point 2 miles south of Makena, means that the presence of beachrock is very unlikely, so the available field time was concentrated in more favorable areas.

No perennial streams reach the shores of East Maui from Kahului Bay to Maliko Bay except at Maliko, nor from Maalaea Bay to far east of Makena. However, east of the two bays, the bedrock lavas extend to the shores with only a thin discontinuous mantle of beaches, so that ground water escapes easily at or near sea level. On the southern coast the ground water is brackish and probably not plentiful, but there must be a substantial outflow along the northern coast. It is noteworthy that there is beachrock on the northern coast, but none on the plentiful beaches of the southern coast. The beachrock on the northern coast consists of an interesting series of five spits and bars, between Spreckelsville and Lower Paia, and occurrences in the wave-washed zone in two bays northeast of Lower Paia. In one of these bays and at the small point north of Spreckelsville beachrock overlies red soil, and at the latter site it also directly overlies a basaltic flow in places. More beachrock is shown in offshore positions in this area than elsewhere in the islands, and the remnants are also farther offshore, suggesting that retreat of sand beaches has been great. Recent retreat is also indicated by undercutting of trees and by historical records. Some of the sand may have been transported to the southwest and added to the beach near Kahului where no beachrock could be found, but additional sand has been removed for construction purposes. One of the beaches at Spreckelsville was covered with drifts of *Ulva*.

Narrow coastal plains, in which no beachrock was found, front Maalaea Bay and Ka-

hului Bay. Cliffs form the coasts of West Maui for 3 miles west of Maalaea Bay on the south, and from Kahului Bay around Nakalele Point nearly to Honokowai on the north. The few sandy beaches on these shores do not contain beachrock.

The rest of the coast, on the west and southwest, consists of a narrow coastal plain. Judging from the low and fairly uniform height of the ground water in the bedrock back of the coastal plain, there must be fairly plentiful points of ground-water escape, but none are known at or above sea level. South of Lahaina there are no exposures of beachrock, but 2 miles to the north there is a small outcrop and another mile farther north there are loose slabs of beachrock. Near Honokowai beachrock in the wave-washed zone extends along more than a mile of shore, in some sections forming a spit or bar 20 to 50 feet offshore of the present beach. Locally, two bars are present. Along some of this shore, recent retreat of a 10-foot cliff of alluvium is indicated by undercutting of large trees, and this retreat is in part responsible for exposing some beachrock. Except for two small outcrops just north of Mahinahina Point, a mile north of Honokowai, beachrock is absent around the rest of West Maui.

AGE

In most areas the beachrock could have been formed very recently, even within the

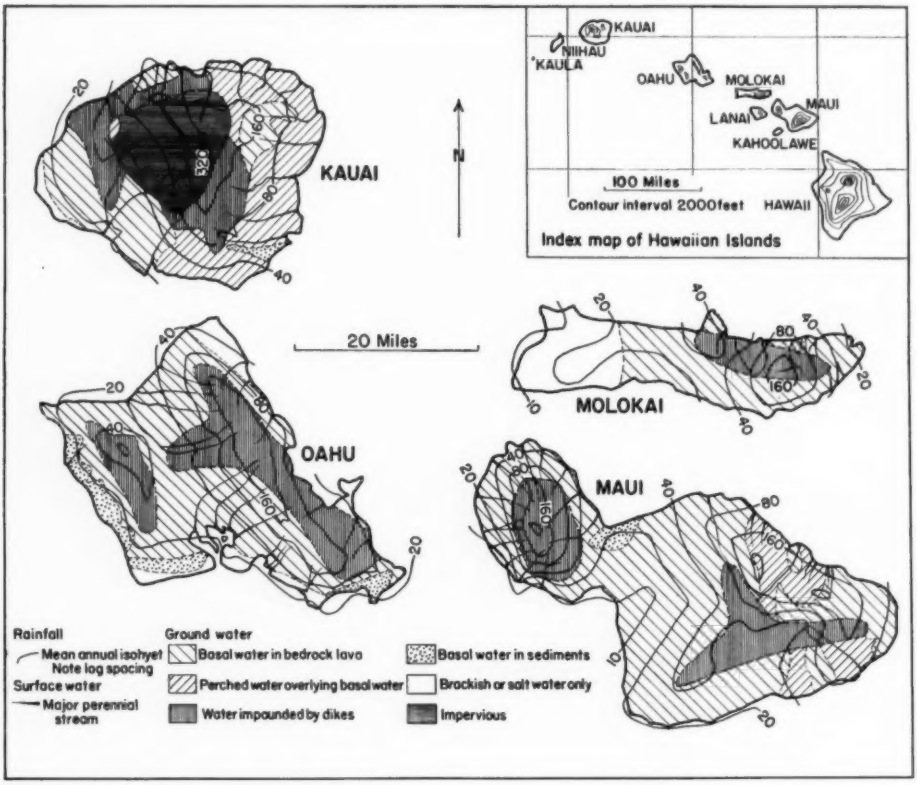

FIG. 18. Map showing hydrology of Kauai, Oahu, Molokai, and Maui.

last decade. A recent age is suggested by the common restriction of the beachrock to positions within the wave-washed zone and to the similarity of its strike and dip to those of the present beach. A somewhat greater age in other places may be indicated by differences in the positions of the beachrock and the present beach (i.e., presence of beachrock spits and whalebacks) indicating retreat of the beach since the beachrock was formed. A locally greater age is also indicated by interbedding of beachrock with other materials. Alluvium is interbedded or overlies beachrock at Waianae and Keaau on Oahu. Near Lower Paia on Maui beachrock rests on red soil that is now intertidal in position.

Some beachrock must be older, and of a greater age than nearby intertidal beachrock, for on Oahu it occurs on raised reef rock as much as 10 feet above present sea level. Elsewhere, ½ and 2½ miles south of Laniloa Point and at Diamond Head on Oahu, beachrock is overlain by eolianite, which at Diamond Head is itself overlain by talus. The greatest age of all, Pleistocene, is indicated for beachrock on the 95-foot Kaena terrace of Oahu.

In summary, beachrock in the Hawaiian Islands may be of three different ages: modern to a few thousand years old (wave-washed zone); probably several to many thousand years old (on raised reef rock and/or overlain by alluvium or eolianite); and Pleistocene age (Kaena terrace). In addition, it is evident that even the youngest of these three ages represents not a single stage of cementation, but rather several to many separate stages. Repeated stages of cementation are well shown by the common presence of reworked beachrock slabs incorporated in later layers and by truncation of earlier layers by later ones.

ECONOMIC VALUE

Beachrock of many tropical islands has long been used for minor construction purposes, such as grave markers and flagstones. Some has also been used to make "flint" artifacts. Slabs of beachrock were quarried from near Hale o Lono on Molokai and transported to Honolulu for decorative use in buildings. It has also been quarried near Barbers Point on Oahu, according to Stearns (1939). Many other beaches are capable of supplying such slabs. From still other localities solid dimension stone, 2 to 4 feet in smallest dimension, can be obtained. Among the best of these localities are: bays on both sides of Kahuku Point, two areas just south of Laniloa Point, and two areas just south of Waianae on Oahu; at Waieli and Nohili on Kauai; and at Kepuhi on Molokai. The economic value, however, is not great because the cut stone probably would have an appearance very similar to concrete made from loose beach sand.

Beachrock has also been found to constitute the best source, on atolls, of aggregate for concrete. The rock is quarried, crushed, screened, and mixed with cement and sea water to form a good grade of concrete (Narver, 1954).

ORIGIN

The main purpose of this investigation was to discover, if possible, the origin of beachrock—at least of the beachrock in the Hawaiian Islands. Altogether, beachrock was noted along approximately 37 miles of the shores, but in such a variety of environments that it is difficult to isolate the least common denominator, or most probable controlling factor.

Absence of beachrock at the ends of points and other areas where loose beach sand is not now present, nor probably ever was present, leads to the obvious conclusion that loose beach sand must be available if beachrock is to form. Beyond this point, generalizations appear to have many exceptions.

Before making the present study, the authors recognized that beachrock is abundant around islets of atolls and relatively rare around high islands of moderately great rainfall such as Guam. The hypothesis was developed that beachrock occurs where the in-

terstitial water of beaches is sea water, which is already saturated with calcium carbonate, and that it should be absent where the interstices are occupied by ground water that has passed only through volcanic rocks and is presumably not saturated with calcium carbonate. In addition, beachrock should be present where the beach contains ground water that has escaped from a wide limestone plain and thus contains a high percentage of calcium carbonate. The basis for this hypothesis is that water that is left in the beach by a falling tide or that rises by capillarity through the beach sand largely evaporates near the sand surface. Any salts originally dissolved in the water are precipitated in the sand where they serve as a cement (Emery and Foster, 1948). Readily soluble salts such as sodium chloride are removed by the next high tide, but salts such as calcium carbonate may remain to form a more permanent cement. In addition, the heating of the beach by the sun during the day tends to reduce the solubility of CO_2 in the interstitial water close to the surface, so that its pH rises. If the water is initially near saturation, calcium carbonate is precipitated (Emery, Tracey, and Ladd, 1954: 45–46). Because sea water contains more calcium carbonate than most ground waters, it seems reasonable to expect that beach sands would be cemented into beachrock more easily where sea water is evaporated than where only fresh water containing little calcium carbonate is evaporated.

On Oahu the hypothesis appears to be supported generally by field data. Beachrock is abundant along the western coast where the rainfall is low and on Mokapu Peninsula, also a low rainfall locality. Conductimetric tests show that interstitial beach water in these areas is sea water; therefore, it is probable that little ground water escapes through these beaches. One of the chief areas of beachrock on Oahu is the northern coast around Kahuku Point, an area where considerable quantities of fresh water escape and where conductimetric and titration tests showed that ground water is associated with beachrock. Titration of four water samples from the bottom of the deepest hole of Figure 5, of three from the loose beach sand, and of three from the ocean water atop the reef flat, yielded average chlorinity values of 2.50, 3.58, and 19.14 parts per thousand, respectively. Comparison of the calcium and chloride concentrations (Table 4) shows that both ions are less abundant in water collected from the hole in beachrock than in sea water, but that the calcium concentration with respect to chloride is about twice as great as in sea water. This high ratio of calcium to chloride in the ground water means that much of the calcium must have been derived from the rocks through which the water passed. Some additional support for the hypothesis can be obtained by consideration of the areas where beachrock is absent. Very little beachrock occurs along most of the eastern coast of Oahu where high rainfall leads to escape of large amounts of surface and ground water. No beachrock whatever is known in Kaneohe Bay, where sea water was found to be diluted

TABLE 4
COMPOSITION OF WATERS

	CALCIUM ppm	CHLORIDE ppm	Ca/Cl	SOURCE OF DATA
Hole through beachrock of Figure 5	144	2,610	0.0552	USC analysis by Dr. Wilson Orr
Sea water (general)	400	18,980	0.02106	Sverdrup, Johnson, and Fleming (1942: 173)
Sea water (Hanauma Bay)	507	19,681*	0.0258	Stearns and Vaksvik (1935: 361)

* Includes nitrate.

by fresh water escaping from volcanic rocks or flowing atop an alluvial plain.

On Molokai the distribution of beachrock fits the hypothesis even better. Beachrock is well developed along the western and southwestern shores, where escape of ground water is probably small because the rainfall is low. Beachrock is absent along the rest of the southern shore. This coast, though itself low in rainfall, receives much ground water from the main ridge of East Molokai which has a high rainfall. Because of the considerable escape of ground water, the nearshore sea water has been diluted, especially in the large artificial fish ponds that were built in ancient times. Brackish water in these ponds supports a crop of mullet, a fish that prefers fresh or brackish water (Hiatt, 1944). In the same area *Ulva*, sea lettuce, is prolific (Abbott, 1947), suggesting that it too prefers dilute sea water. The only other areas of abundant fish ponds are along Kaneohe Bay and the southeastern shore of Oahu, and here also beachrock is absent.

On Maui a reversed situation exists. Beachrock is absent or rare around the leeward coast of low rainfall and probably little ground water, but abundant near Lower Paia where considerable dilution by ground water is known. In this area the ground water comes directly from the volcanic rocks to the beach, as it does along the southern shore of Molokai. Thus, on Maui the distribution of beachrock does not fit the original hypothesis.

On Kauai, as on Maui, beachrock appears to be independent of the kind of interstitial water. The most extensive area of beachrock is the western alluvial coast, a situation similar to the dry western coast of Oahu where beachrock is abundant. However, beachrock also occurs in small patches around other shores of Kauai, and some of these patches lie at the mouths of perennial streams.

Altogether, the evidence from distribution shows no unequivocal preference of beachrock for beaches having interstitial water composed of sea water, ground water from limestone plains, or ground water from volcanic rocks. If the nature of the interstitial water were a dominant control, we must be prepared to say either that areas which now contribute much ground water directly from volcanic rocks formerly contributed little ground water, and that beachrock in those areas was formed during the past, or that details in the pattern of the ground-water flow, not predictable except possibly by a study more intensive than that reported, lead to important variations in the nature of the interstitial water in the beaches. The first conclusion does not appear to be reasonable, and the second begs the question. We must look, therefore, for other possible explanations or for supplementary factors.

One such explanation was proposed by Cloud (1952) who suggested that blue-green algae, known to live in the top quarter-inch of some beach sands, may cement the sand through their biochemical activities. Cementation of individual layers, 2 feet or more thick, appears to be a fatal objection, because the algae are probably restricted to the topmost fraction of an inch in order to receive enough sunlight for photosynthetic activities. Another possible explanation proposed by Nesteroff (1955: 33) and Ranson (1955) is that amorphous calcium carbonate is deposited between the sand grains by the action of bacteria living in organic material deposited with the sand. However, there seems to be no evidence of the presence of large amounts of organic material in the Hawaiian beachrock and the organic content of the sand is extremely low (Oahu samples 1, 5, 8, 15, and 16 of Table 1 have organic carbon percentages of only 0.10, 0.16, 0.14, 0.22, and 0.09, respectively).

Merrin (1955), who studied beachrock in Puerto Rico, proposed that beachrock is restricted to areas of stable beaches; however, many of the Hawaiian beaches having beachrock are known to undergo large changes seasonally and because of storms. In fact, some of the areas of beachrock on Kauai

shown by Figure 14 were covered by sand at the time of our mapping and were discovered by Dr. Douglas Inman of Scripps Institution of Oceanography during a later visit.

In short, although beachrock is abundant in the Hawaiian Islands and elsewhere, we do not know how it forms. Mapping its distribution is not by itself a sufficient source of data to solve the problem of origin. Perhaps the making of many additional chemical analyses of interstitial waters of beaches would be a helpful supplement to mapping.

REFERENCES

ABBOTT, I. A. 1947. Brackish-water algae from the Hawaiian Islands. *Pacific Sci.* 1 (4): 193–214.

CLOUD, P. E. 1952. Preliminary report on geology and marine environments of Onotoa Atoll, Gilbert Islands. *Atoll Res. Bul.* No. 12: 1–73.

EMERY, K. O. In press. Marine geology of Guam. *U. S. Geol. Survey, Prof. Paper.*

EMERY, K. O., and J. F. FOSTER. 1948. Water tables in marine beaches. *Jour. Mar. Res.* 7:644–654.

EMERY, K. O., J. I. TRACEY, JR., and H. S. LADD. 1954. Geology of Bikini and nearby atolls. *U. S. Geol. Survey, Prof. Paper* 260–A: 1–265.

GARDINER, J. S. 1931. *Coral reefs and atolls.* xiii + 181 pp., 15 pls., 4 maps. Macmillan Co., New York.

GINSBURG, R. N. 1953. Beachrock in south Florida. *Jour. Sed. Petrology* 23: 85–92.

HIATT, R. W. 1944. Food-chains and the food cycle in Hawaiian fish ponds, II Biotic interaction. *Amer. Fish. Soc., Trans.* 74: 262–280.

ILLING, L. V. 1954. Bahaman calcareous sands. *Amer. Assoc. Petrol. Geol., Bul.* 38: 1–95.

MERRIN, S. 1955. Beachrock in northeastern Puerto Rico. *First Carribean Geol. Congress, Antigua, British West Indies.* 15 pp. [mimeographed.]

NARVER, D. L. 1954. Good concrete made with coral and sea water. *Civ. Engin.* 24: 654–658, 725–728.

NESTEROFF, W. D. 1955. Les récifs coralliens du Banc Farsan Nord (Mer Rouge). *Résult. Sci. des Campagnes de la "Calypso."* 1: 1–53.

NEWHOUSE, J. 1954. Ecological and floristic notes on the Myxophyta of Raroia. *Atoll Res. Bul.* No. 33 (2): 42–54.

RANSON, G. 1955. La consolidation des sédiments calcaires dans les régions tropicales. [*Paris*] *Acad. des Sciences, Compt. Rend.* 240: 640–642.

REVELLE, R., and K. O. Emery. In press. Chemical erosion of beach rock and exposed reef. *U. S. Geol. Survey, Prof. Paper* 160–W.

STEARNS, H. T. 1935. Pleistocene shore-lines on the islands of Oahu and Maui, Hawaii. *Geol. Soc. Amer. Bul.* 46: 1927–1956.

——— 1939. *Geologic map and guide of the Island of Oahu, Hawaii.* x + 76 pp., 23 figs., 1 map. Ter. of Hawaii, Div. Hydrog. Bul. 2. Honolulu.

STEARNS, H. T., and K. N. VAKSVIK. 1935. *Geology and ground-water resources of the Island of Oahu, Hawaii.* xx + 479 pp., 33 pls., 34 figs. Ter. of Hawaii, Div. Hydrog. Bul. 1. Honolulu.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1942. *The Oceans.* x + 1087 pp., 265 figs., 7 charts. Prentice-Hall Inc., New York.

WENTWORTH, C. K. 1938. Marine bench-forming processes, I. Water-level weathering. *Jour. Geomorphol.* 1: 6–32.

——— 1939. Marine bench-forming processes, II. Solution benching. *Jour. Geomorphol.* 2: 3–26.

——— 1944. Potholes, pits, and pans: Subaerial and marine. *Jour. Geol.* 52: 117–130.

Fritillaria arafoera n. sp., a Form of the Sibling Species: *Fritillaria haplostoma*–Complex (Appendicularia: Chordata)

TAKASI TOKIOKA[1]

AN APPENDICULARIAN specimen found in one of the plankton samples hauled by Mr. Sagara in the Arafura Sea during the biological survey of the pearl oyster fishery ground seems to represent a new species, which is described here and named *Fritillaria arafoera*. The species is considered to show an extreme form of the sibling species forming the *Fritillaria haplostoma*–complex, in which *F. abjornseni* Lohmann and many of Essenberg's species are included. The latter are discussed taxonomically in the last part of the article.

Fritillaria arafoera n. sp.

TRUNK: This is a small species. Trunk is 440 μ in length and quite wide, being widest on the level of the posterior part of the oikoplast-epithelium and with the value of width/length about 0.4. The body is slightly bent ventrad at the insertion point of the tail, situated slightly posterior to the middle of the body. It is rather compressed dorsoventrally excepting the anterior one third of the trunk, where a remarkable hood is formed on the oikoplast-epithelium, the posterior margin of which almost reaches the anterior end of the stomach. The anterior half of the pharynx is fairly narrow, the upper lip is roughly triangular in outline and protruded anteriorly beyond the frontal end of the hood. Endostyle short, curved only slightly; a ciliated band encircles the buccal cavity on the level of the anterior end of the endostyle. Spiracles comparatively large, roundish in outline and well separated. Oesophagus short, stomach globular and with nearly smooth surface. Intestine with three glandular appendages (gl. ap. 1–3, Fig. 1) arranged dorsoventrally, the middle one (gl. ap. 2, Fig. 1) much larger than the other two. This middle appendage assumes superficially a glandular appearance and it is treated here as a glandular appendage. However, it is possible that this is merely a part of the intestine proper. Ovary is spherical and testis is an elongate mass, genital region of the trunk is much shorter than the rest. Gland cells are distributed as follows: one at the posterior end of the testis, one at each posterolateral corner of the trunk, one at the outer side of each spiracle and one near each posterolateral edge of the hood.

TAIL: Tail is 1380 μ in length. Tail length/trunk length is 3.1. The proximal end of the tail fin assumes an appearance of sloping shoulders instead of angular shoulders frequently met with in common fritillarians. Musculature wide, but distally diminishing in breadth rather rapidly. Thus it is narrowed nearly to the breadth of the chorda in the posterior part, although it definitely reaches the distal end of the chorda. Width of tail musculature/tail length ($\times$100) is 11.8 and width of chorda/maximum width of tail musculature ($\times$100) is 17. The distal end of the tail fin is fringed with slightly thickened margin, this probably indicates the existence of cilia at this portion.

REMARKS

The present new species resembles most closely *Fritillaria abjornseni* Lohmann from the neighbouring waters of Fremantle and *Fritillaria lohmanni* Essenberg and *F. tereta* Essenberg from the San Diego region in smaller size of body and general appearance

[1] Seto Marine Biological Laboratory, Sirahama, Wakayama-ken, Japan. Manuscript received October 5, 1955.

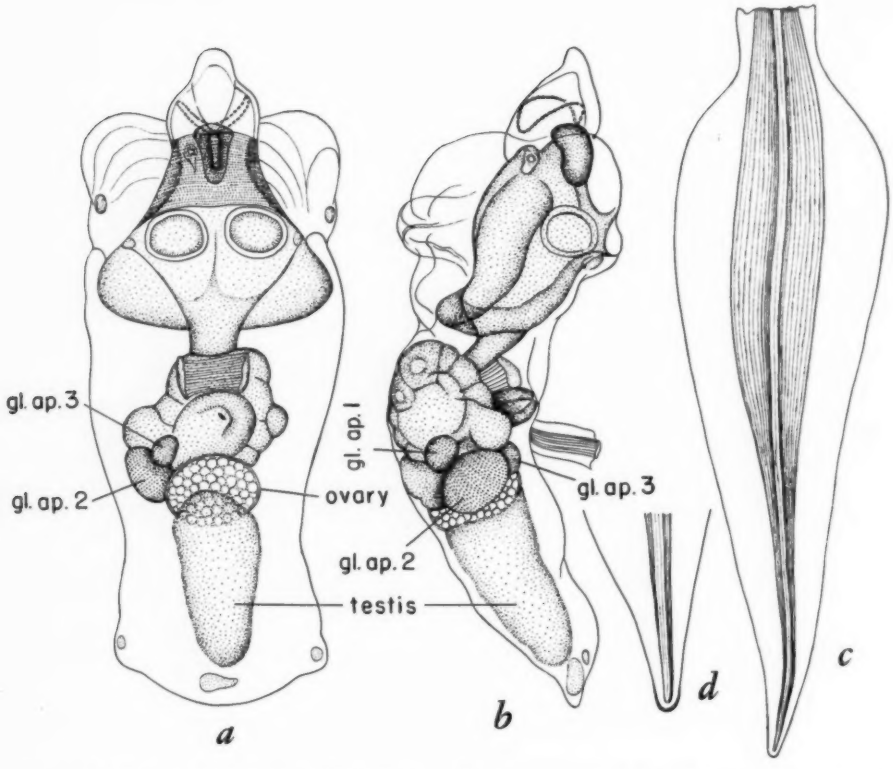

FIG. 1. *Fritillaria arafoera* n. sp.: *a*, Ventral aspect of trunk, ×200; *b*, right lateral aspect of trunk, ×200; *c*, tail, ×73; *d*, distal portion of tail, ×200. gl. ap.—glandular appendage.

of both trunk and tail. It is especially related to *F. lohmanni* in that three glandular appendages are found on the intestine. In *F. arafoera*, however, the middle one of the three accessory blind sacs (=glandular appendages) may possibly represent a part of the intestine proper. In both of Essenberg's species, moreover, the trunk is much more elongate than in the present one and the distance between the posterior margin of the oikoplast-epithelium and the anterior edge of the stomach is much greater than in the Arafuran specimen. Thus, *F. abjornseni*, *F. lohmanni*, and *F. tereta* conform well to one another in that both spiracles are in contact with each other at the inner side, and this feature is considered by Lohmann (1909) as the critical characteristic of *Frit. abjornseni*. Consequently these three species are considered to be treated as forms belonging to a single species, the name of which should be *Fritillaria abjornseni* according to the law of priority. In the present species, however, the two spiracles do not touch as shown in Figure 1A. For these reasons, I prefer at present to treat the present specimen as a new species and name it *Fritillaria arafoera*.

As I stated previously (Tokioka, 1951: 4), *F. haplostoma* shows a considerable range of variation in body length. Small specimens of *F. haplostoma* described in an earlier paper (Tokioka, 1955: 259), smaller forms reported

in the same paper (p. 256) under the name of *F. abjornseni* and several forms allied to *F. haplostoma*, described by Essenberg (1926) under different names, seem to combine *F. abjornseni* with typical forms of *F. haplostoma* as far as body size is concerned.

Considering the structure of the trunk, the shape of the spiracles seems not to be accepted as an important characteristic, because it varies from elongate to round, correlated with decrease of body size. Even in large specimens, the spiracles may sometimes be roundish as they are indicated in the original figure by Fol (1872, pl. VI, fig. 6). The distance between the posterior end of the oikoplast-epithelium and the frontal edge of the stomach seems to diminish regularly according to the shortening of the trunk. The surface of the stomach may be considerably roughened by protrusion of some wall cells in some individuals although it is usually smooth in smaller specimens. The proportional length of the genital region diminishes with the decrease of the body length.

The tail of typical *F. haplostoma* is characterized by narrow musculature and exposed posterior portion of the chorda. The musculature scarcely reaches beyond the lateral sides of the chorda in typical forms, but in some individuals, especially in smaller ones, it is slightly wider than the chorda. In *F. abjornseni* Lohmann (1909), C/M × 100 measured on his figure is 22.2, while it is 16.6 in *F. tereta* and 20.8 in *F. lohmanni* both also measured on figures. In specimens reported by Tokioka (1955) under the name of *F. abjornseni*, the value is about 33. It is 36.4 in *F. lucibila* Essenberg and about 50 in *F. limpida* Essenberg. These data seem to support the idea that the narrow tail musculature of typical *F. haplostoma* continues to the wider tail musculature of *F. abjornseni* through several intermediate forms. The exposed posterior portion of chorda is fairly long in typical forms of *F. haplostoma*, but it is extremely short in forms described by Tokioka (1955) under the name of *F. abjornseni*. Unfortunately, as no description is given about this feature on the type specimen of *F. abjornseni* and many forms reported by Essenberg, further consideration of this characteristic must be abandoned.

According to Lohmann (1909) the most important characteristics differentiating *F. ab-*

TABLE 1

TEN FORMS OF THE *Fritillaria haplostoma* COMPLEX GROUPED BY DIFFERENCES IN THREE CHARACTERISTICS
(Values of width of chorda and maximum width of tail musculature in species of Lohmann and Essenberg were measured on published figures)

NAME OF SPECIES	LENGTH OF TRUNK	$\frac{\text{WIDTH OF TRUNK}}{\text{LENGTH OF TRUNK}}$	$\frac{\text{CHORDA}}{\text{MUSCLE}} \times 100$
Group I			
Fritillaria lucibila Essenberg	850 μ	0.16	36.4
Fritillaria limpida Essenberg	700	0.2	50
Group II			
Fritillaria campila Essenberg	550	0.2	31.8
Fritillaria tacita Essenberg	500	0.2	26
Fritillaria abjornseni (described by Tokioka in 1955)	440–740	0.25	33
Group III			
Fritillaria amygdala Essenberg	340	0.33	22.7
Fritillaria lohmanni Essenberg	370	0.16	20.8
Fritillaria tereta Essenberg	400	0.25	16.6
Fritillaria abjornseni Lohmann	250	?	22.2
Group IV			
Fritillaria arafoera n. sp.	440	0.4	17

jornseni from *F. haplostoma* are the smaller size, the spiracles touching each other at the inner side and the tail musculature being much wider than the chorda. In Table 1 I attempt to arrange various allied forms of *F. haplostoma* and *F. abjornseni* systematically on these standards.

Group I may safely be accepted as proper *F. haplostoma*, because the tail musculature is rather narrow and the spiracles are comparatively small and situated apart from each other. The four forms of Group III are undoubtedly united into a single species, *F. abjornseni*, because the tail musculature is very wide and both spiracles touch each other at the inner side. Group II is considered to involve intermediate forms between Groups I and III in the feature of the tail musculature. The spiracles are separated from each other, but they are comparatively large as in Group III, except in *F. tacita*. The exposed posterior portion of the chorda is extremely short in the last member of the group as compared with that in the typical form of *F. haplostoma*, and the distance between the posterior end of the oikoplast-epithelium and the frontal edge of the stomach is very slight in the last two of the group. For these reasons, I prefer to treat this group conveniently under *F. abjornseni*, by extending the definition of this species so as to include forms which have spiracles separated from each other. *F. arafoera* is characterized by a remarkably wide trunk, separated spiracles, wide tail musculature, basal part of the tail fin like sloping shoulders and absence of the exposed distal portion of the chorda, although it is closely related to *F. abjornseni*.

I am here placing the ten forms considered in the table into three species: *F. haplostoma*, *abjornseni* and *arafoera*. And it seems very reasonable to consider these three species as sibling species forming a *Fritillaria haplostoma*-complex, in which *F. magna* Lohmann and *F. aberrans* Lohmann may also be included when more abundant data concerning the feature of the alimentary organ are accumulated and considered carefully. However, the mechanism which causes this wide variation is still unknown. It is clear that both *F. abjornseni* and *F. arafoera* are found mostly in coastal waters and smaller forms of *F. haplostoma* are met with more frequently in coastal water rather than in the pure oceanic water. Lastly, the present new species certainly may be considered as being situated at the extremity of a wide range of variation, opposite to the typical *F. haplostoma*.

I wish to express here my hearty thanks to Mr. Sagara for his kindness in giving me a chance to examine the present precious material.

REFERENCES

ESSENBERG, C. E. 1926. Copelata from the San Diego Region. *Calif. Univ. Pubs., Zool.* 28(22): 399–521, 170 figs.

FOL, M. H. 1872. Études sur les Appendiculaires du détroit de Messine. *Soc. de Phys. et Hist. Nat. Genéve, Mém.* 21(2): 445–499, 11 pls.

LOHMANN, H. 1896. Die Appendicularien der Plankton-Expedition. *Ergebn. der Plankton-Exped.* . . . 2 (E, c), 148 pp., 24 pls.

——— 1909. Copelata und Thaliacea. In, *Die Fauna Südwest-Australiens.* Vol. 2, No. 10 (pp. 143–149). Gustav Fisher, Jena.

TOKIOKA, T. 1951. Pelagic tunicates and chaetognaths collected during the cruises to the New Yamato Bank in the Sea of Japan. *Seto Mar. Biol. Lab., Pubs.* 2(1): 1–25, 12 figs., 6 tables, 1 chart.

——— 1955. General consideration on Japanese appendicularian fauna. *Seto Mar. Biol. Lab., Pubs.* 4(2–3): 251–261, 6 figs.

A New Gadiform Fish from the Continental Slope off Southeastern Australia

T. R. COWPER[1]

THE SPECIMEN which is here described was foul-hooked while longlining from the F.R.V. "Derwent Hunter" on the continental slope east of Tasmania in February 1953, and, although this area has been fished on a number of occasions subsequently, no further specimens have been taken. Unfortunately, as a result of being foul-hooked, the abdominal wall of the specimen was damaged; anteriorly below the origins of the pectoral fins and laterally on the left hand side, the former injury being apparent in Figure 1.

It is assigned to the genus *Lepidion* Swainson (1838) of the family Moridae because it exhibits the following characters: an elongate, compressed body; scales cycloid, covering whole of the body, head, and bases of fins; snout short and blunt in profile; maxilla extending to vertical below eye; barbel on chin; fine teeth in bands on both jaws; two dorsal fins narrowly separated; first dorsal fin with anterior ray filamentous and produced; anal fin single, deeply indented; caudal subtruncate; ventrals narrow, of seven rays, the two uppermost being long and filamentous. *Lepidion* was transferred from the family Gadidae to Moridae by Svetovidov in 1948.

Though this specimen has a number of characters in common with other members of the genus it has not been possible to relate it to any one of them. The characters which are recurrent in the majority of descriptions of members of the genus (Gunther, 1862, 1887; Johnson, 1862; Goode and Bean, 1895; Franz, 1910; Gilchrist, 1922; Barnard, 1925; Tanaka, 1927; Svetovidov, 1936; Maul, 1952) have been selected for purposes of comparison in establishing this specimen as a new species.

Lepidion microcephalus, sp. nov.
Figs. 1, 2

Head comparatively small, being 5.75 in the total body length and 1.75 in the distance between the origin of the ventral fin and anus. Eye large, 3.125 in the head, 1.25 times the length of the snout, twice that of the barbel, and 1.66 that of the interorbital width. Maxilla extending below the anterior third of the orbit. Numerous fine teeth in bands on the premaxilla and mandible. Lower jaw shorter than the upper. Snout almost square in profile. Posterior nostril considerably larger than the anterior which has an elevated, semitubular border posteriorly. Greatest depth of body 5.25 in the total length and occurring below the 8–9th ray of the second dorsal. First dorsal fin of 5 rays, the anterior ray long and filamentous being 1.33 times the head length. Base of first dorsal equal to least depth of caudal peduncle. Second dorsal fin of 54 rays having its longest rays in the anterior half and in the posterior portion in the region of the 42nd ray. Ventral fins originating under the posterior 0.4 of the head, close together, having 7 rays, the upper two being long and filamentous, the lower of these being the longer. Length of ventral fin exceeds that of the pectoral. Pectoral fin of 21 rays, originating anterior to the vertical from the origin of the first dorsal and extending to the vertical below the 5th ray of the second dorsal. Anal fin of 46 rays, originating under the vertical from the 14th ray of the second dorsal, having

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FIG. 1. *Lepidion microcephalus*, sp. nov. Holotype in Tasmanian Museum. Type locality: 12 miles east of Schouten Is., Tasmania, 400–420 fm.

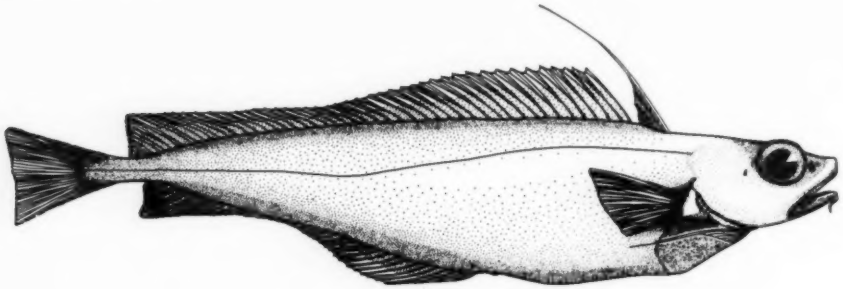

FIG. 2. *Lepidion microcephalus*, sp. nov. Drawing to show details of structure.

its longest rays in the anterior quarter and in the posterior portion in the region of the 35th ray; median rays considerably shorter producing a pronounced indentation in that portion of the fin. Caudal fin of 42 rays, subtruncate, barely emarginate. Lateral line originating at back of head above posterior edge of operculum and descending posteriorly to a point above the anterior 0.33 of the anal fin from which point it runs parallel with the main axis to the end of the caudal peduncle. Thirteen or 14 scales between the first dorsal fin and lateral line; 180 oblique rows of scales in the lateral line. Scales small, cycloid, covering head and origins of all fins. Colour on capture, mottled pinkish brown on grey with black edges to the second dorsal and anal fins. Radial formula: D.5/54; A.46; P.21; V.7; C.42.

DISCUSSION

In this specimen the head length is relatively less than that of all other described members of the genus. The eye diameter is relatively greater than that of all others but *L. eques* (Günther) and *L. lepidion* (Risso) with which it closely corresponds. The depth of body is relatively greater than that of *L. inosimae* (Günther) and less than that of all others with the exception of *L. natalensis* Gilchrist and *L. schmidti* Svetovidov with which it agrees. The length of snout is relatively less than that of all others but *L. eques*, *L. natalensis*, and *L. ensiferus* (Günther). The

relative distance between the root of the ventral fins and anus, when expressed as a fraction of the head length, is considerably greater than that of all other described members of the genus. The number of scales in the lateral line is greater than that of *L. natalensis*, *L. lepidion*, and *L. modestus* (Franz), fewer than that of *L. guentheri* (Giglioli), *L. oidema* (Tanaka), and *L. capensis* Gilchrist, but equal to that of *L. eques*. The number of scales in the distance between the first dorsal fin and lateral line is fewer than that of all other members of the genus but *L. lepidion*, with which it agrees. The radial formula is different from that of all others described.

This Australian specimen cannot be identified from the key contained in a synopsis of the genus (Norman, 1935), though its close affinity to the group containing *L. lepidion* and *L. eques* is indicated. It is excluded from this group, however, by the relative depth of the caudal peduncle, and from the contained species by the radial formula, relative length of head, relative length of filamentous rays of ventrals and first dorsal, shape of caudal, and by scale counts along the lateral line and between first dorsal fin and lateral line.

From the foregoing then it would seem that, although the Australian specimen has affinities with most other members of the genus, and more particularly with *L. eques* and *L. lepidion*, the differences, in radial formula, body proportions such as relative head length and eye diameter, together with scale counts, are real and therefore separate it from all other members of the genus.

Holotype

Taken 12 miles east of Schouten Island, Tasmania, from 400–420 fathoms and deposited in the Tasmanian Museum. Registered No. 13225/D160. Total length, 451 mm.

ACKNOWLEDGMENT

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REFERENCES

BARNARD, K. H. 1925. A monograph of the marine fishes of South Africa. Part I. *So. African Mus., Ann.* 21: 1–418, 18 figs., 17 pls.

FRANZ, V., VON. 1910. Die Japanischen Knochenfische der Sammlungen Haberer und Doflein. *Bayer. Akad. der Wiss., Abhandl., Suppl.* 4: 1–135, 11 pls.

GILCHRIST, J. D. F. 1922. Deep sea fishes procured by the S.S. "Pickle." Part I. *Union So. Africa, Fish-Mar. Biol. Survey, Rpt.* 2 (Spec. Rpt. 3): 41–79, 6 pls.

GOODE, G. B., and T. H. Bean. 1895. *Oceanic ichthyology*. xxxv + 553 pp., atlas. Smithsonian Institution, Washington.

GÜNTHER, A. 1862. *Catalogue of the fishes in the British Museum*. Vol. 4, xxi + 534 pp. British Museum, London.

——— 1887. Report on the deep sea fishes collected by H.M.S. Challenger during the years 1873–1876. Report on the Scientific Results of the voyage of H.M.S. Challenger . . . Vol. 22, lxv + 335 pp., 73 pls. Great Britain, Edinburgh, London and Dublin.

JOHNSON, J. Y. 1862. Notes on rare and little known fishes taken at Madeira. *Ann. and Mag. Nat. Hist.* III, 10(57): 166–169.

MAUL, G. E. 1952. Monografia dos peixes do Museu Municipal do Funchal. *Mus. Munic. Funchal, Bol.* 6 (Art. 15 & 16): 18–23.

NORMAN, J. R. 1935. Coast fishes. Pt. I. The South Atlantic. *Discovery Reports*. Vol. 12, 55 pp. Cambridge University, Cambridge.

SVETOVIDOV, A. N. 1936. *Lepidion schmidti* eine neue fischart. *Zool. Anz.* 113: 266–269.

——— 1948. Fishes, in Fauna of the U.S.S.R. Vol. 9, pt. 4, 221 pp., 72 pls. Academy of Science U.S.S.R., Moscow, Leningrad.

TANAKA, S. 1927. *Figures and descriptions of the fishes of Japan* . . . Vol. 41 [Vol. 3], 24 pp. [785–808], 2 pls. Daichi shoin, Tokyo.

A New Subfamily of Urostylidae from Borneo (Hemiptera: Heteroptera)

W. E. China and James A. Slater[1]

Through the kindness of Dr. R. I. Sailer of the United States National Museum we recently have had the opportunity to study a very remarkable insect from Borneo. With some hesitation we place this insect in the pentatomoid family Urostylidae as a new subfamily, although the differences between this new species and previously known urostylids are of considerable magnitude.

The systematic position of this curious insect is of considerable interest. The presence of ventral abdominal trichobothria places *Saileriola* in the Trichophora of Tullgren (1918). Although trichobothria are absent in some Pentatomorpha (Leston, Pendergrast and Southwood, 1954) such as the lygaeid genus *Oxycarenus* and the plataspid *Lestonia*, so far as is known no cimicomorphs possess trichobothria. Likewise the presence of arolia and pseudoarolia precludes many cimicoid groups. Once the position of the species in the trichophora is established, one is faced primarily with the problem of pentatomoid or lygaeoid affinities. The apparently five-segmented antenna is of course pentatomoid, although certainly not definitive; some pentatomoids possess four- and even three-segmented antennae, and five-segmented antennae are known to occur in such dissimilar families as the Hebridae and Nabidae. So far as we know, however, five-segmented antennae are unknown in the Lygaeidae whereas they do represent the predominant condition in the Pentatomoidea. The lack of a claval commissure (Fig. 1*a*) is rather characteristic of Pentatomoidea, whereas the condition occurs only rarely in the Lygaeidae (i.e. *Geocoris* and *Chauliops*). The partial fusion of the ventral abdominal segments (Fig. 1*b*) is reminiscent of some Lygaeidae (many Rhyparochrominae, Pamphantinae, *Artemidorus*, etc.), but similar fusion occurs in the Pentatomoidea (*Lestonia*, for example). The peltoid head shape and widely separated coxae are typical pentatomoid characters. In Lygaeidae the coxae are usually closely approximated, although widely separated at times as in some Blissinae such as *Bochrus*. The aedeagus in *Saileriola* closely resembles the pentatomoids rather than the Lygaeidae. The vesica is short with definite conjunctival appendages. The long fine spiral vesica found in the majority of Lygaeidae (but not in the Pachygronthinae and Heterogastrinae) is definitely lacking. The venation of the hind wing (Fig. 2*e*) is unlike either group, having obviously undergone extreme reduction with the loss of the hamus, distal portion of the cubitus, intervannals, vannals, and jugal veins (terminology follows Leston, 1953).

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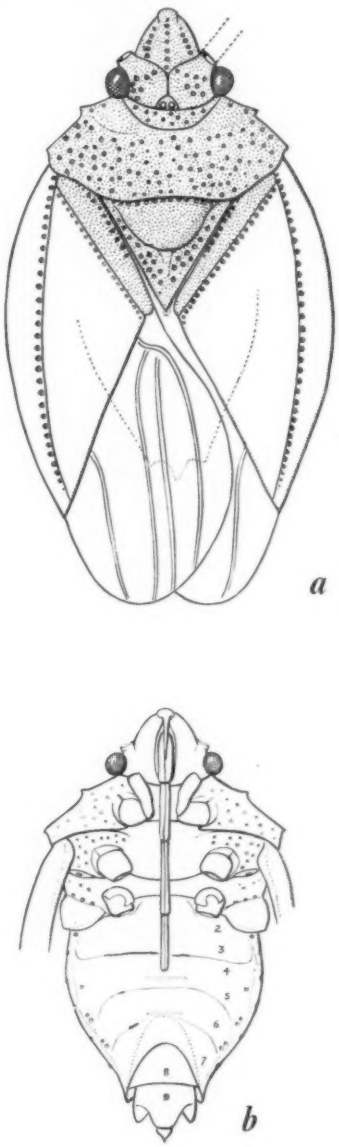

FIG. 1. *Saileriola sandakanensis* n. sp.: *a*, Dorsal aspect of body; *b*, ventral aspect of body showing spiracles and trichobothria, dorsal nymphal scent gland scars shown by dotted lines.

It would appear from the rather general characters mentioned above that we are dealing with a rather anomalous pentatomoid. There is some further evidence to support this viewpoint and also to indicate that the affinities of *Saileriola* are with the Pentatomoidea.

In a number of important features *Saileriola* shows relationship to the Urostylidae, in which family we place it for the present. This family must represent the Proto-Trichophora at the base of the Pentatomidae, Coreidae, and Lygaeidae. *Saileriola* resembles the Urostylidae very closely in the structure of the pygophore (Fig. 3*a*) (see Yang, 1938), the elongate eighth segment of the male, the simple legs, the venation of the hemelytral membrane, the regular punctures of the corium and clavus (also true of many Lygaeidae), and, a feature that we consider of great importance, the position and shape of the area of antennal insertion (Fig. 2*a*). This latter feature has often been used to separate the Coreidae from the Pentatomidae and Lygaeidae. In *Saileriola* this area is more or less dorsal, i.e., placed slightly above the middle line of the eye, as in the Coreidae. However, in the primitive pentatomoid family Urostylidae the insertion of the antennae is exactly as it is in *Saileriola* and the wide annulate antenniferous tubercles are identical. In the genus *Urostylis* the ocelli are placed close together as they are in *Saileriola*. The peltoid head, trochalopodous coxae, pseudarolia, and number and position of the nymphal scent gland scars also indicate a urostylid relationship. Furthermore, in some urostylids an obsolete vertex suture is present as in *Saileriola*, although this may represent a neotinic feature rather than be of phylogenetic importance.

Saileriola does have important features not found in other urostylids and differs from them mainly by virtue of the structure of the metathoracic scent gland peritreme, number and position of trichobothria, position of the spiracles, venation of the hind wing and some structural aspects, and relative size of the

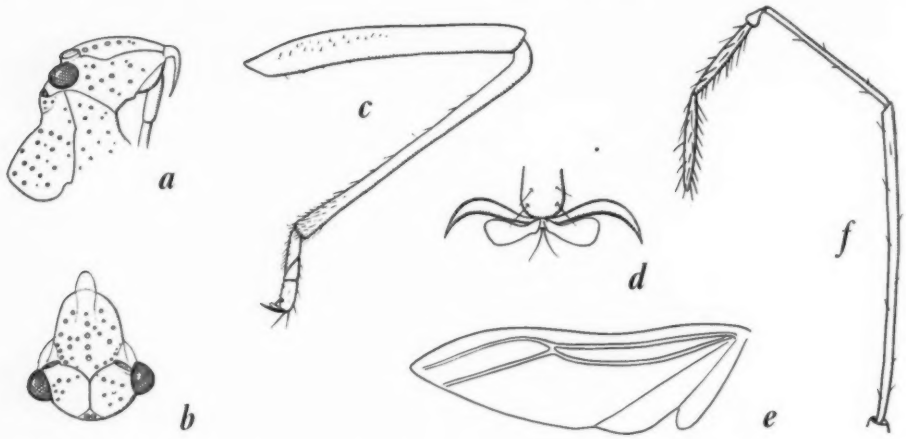

FIG. 2. *Saileriola sandakanensis* n. sp.: *a*, Lateral aspect of head and pronotum; *b*, cephalic aspect of head; *c*, metathoracic leg; *d*, apical portion of tarsus showing claws, arolia, and pseudarolia; *e*, hind wing; *f*, antenna.

pygophore and aedeagus. The extremely small size of the insect is not approached by any of the previously known Urostylidae.

SAILERIOLINAE, new subfamily

Vertex sutures present; antennae five segmented, first segment extending considerably beyond apex of head, longer than length of head and pronotum combined, curving slightly outward, third segment very short, subglobular; antenniferous tubercles exerted and visible dorsally; ocelli present and nearly contiguous on mid-line; bucculae short, about one-half length of head; rostrum attaining fourth abdominal sternite; lateral pronotal margins reflexed; spiracles lateral (except ventral on segment two); venation of hind wing reduced to radius, portion of medius and basal portion of cubitus; lateral trichobothria present on fourth, fifth and sixth abdominal segments, the latter two segments with a pair of trichobothria the former with a single one.

Type genus: *Saileriola*, new genus.

SAILERIOLA, new genus

Head strongly deflexed, antennae arising laterodorsad, slightly above median lateral line through eyes, antenniferous tubercles annuliform more or less semicircular; labium four segmented; cuneus and claval commissure absent; meso- and metasternum noncomposite; abdomen with six pairs of spiracles; coxae trochalopodous; no prosternal stridulatory sulcus; median trichobothria absent; two linear dorsal scent gland scars present between tergites four and five and five and six; tarsi three segmented, claws apical, pseudoarolia present.

Type species: *Saileriola sandakanensis*, new species.

This new genus will run to *Urostylis* in Yang's (1939) key to the urostylid genera, but is abundantly distinct as discussed above.

Saileriola sandakanensis, new species

Head, thorax, scutellum, clavus, and coarse punctures on corium adjacent to claval suture and along inner margin of embolium bright mahogany brown; corium and membrane hyaline; body coarsely punctured as follows: head, thorax, scutellum basally and laterally, median basal portion of clavus, a single series on corium along claval suture and a second series running through corium just lateral of

embolium (R + M); entire body nearly glabrous throughout.

Head with clypeus distinctly longer than jugae, vertex with a median suture that becomes bifid and proceeds to lateral margins just anterior to antenniferous tubercles; ocelli nearly contiguous, near base of head on meson, area of head basad of the suture "arms" strongly convex, eyes contiguous with anterolateral pronotal angles, bucculae moderately elevated, labium elongate reaching middle of abdomen, first segment barely attaining base of head, third segment reaching apices of metacoxae, length of head 0.80 mm. (maximum), 0.50 mm. (dorsal view), width across eyes 0.78 mm., interocular space 0.48 mm.; pronotum strongly transverse, anteriorly with broad collar-like area with large, smooth impunctate callus on either side, lateral margins bearing a distinct tooth, small tooth present at humeral angles, margins somewhat flanged and recurved dorsad, posterior margin sinuate, length of pronotum 0.50 mm., maximum pronotal width 1.43 mm.; scutellum large, triangular, reaching apex of clavus, basal half strongly swollen, smooth and shining, laterally and on terminal half flat with a short obscure median carina that does not reach apex, length scutellum 0.62 mm.; meso- and metasterna lacking either a carina or sulcus, metasternal scent gland openings placed at anterior margin of metapleuron, evaporating area simple and relatively undifferentiated; hemelytra extending far beyond apex of abdomen, corium semihyaline, membrane with four longitudinal veins and no basal cell, the middle two arising from base of inner (cubital) vein, distance from apex of clavus to apex of corium 1.02 mm., distance from apex of corium to apex of membrane 0.50 mm.; hind wing with venation markedly reduced, hamus, antevannal, intervannals, vannals and jugal absent leaving an elongate basal cell formed by R + M anteriorly and Cu posteriorly and a pair of veins, R and M, proceeding distally from the R + M fusion area, vannal fold single; abdominal segments showing marked fusion with distinct sutures visible only between segments three and four, five and six, and six and seven, none of the sutures apparently completely reaching the lateral abdominal margin; no distinct connexival sutures; eighth abdominal segment considerably longer than wide, entirely telescoped into segment seven; pygophore (9th) large, longer than wide with two tooth-like prominences on the relatively small genital atrium, each tooth bearing tuft of mesally directed bristles, small tooth between base of larger tooth and pygophore opening; parameres elongate, slender, linear, with apex slightly clubbed; anal segment (proctiger) semicircular, fringed with short bristles; posterior margin of pygophore above with acute triangular spatulate process; aedeagus typically pentatomoid with median sclerotized paravertical appendage, three pairs of conjunctival appendages and valviform theca; legs simple, mesothoracic and metathoracic coxae very widely separated, coxae very short, trochanters long, hind femora with scattered short, basally tuberculate bristles, tibiae feebly pubescent along under side, more densely so toward apex, first and third tarsal segments longer than segment two, claws widely divergent and narrowly acuminate, pseudoarolia large and flap-like, arolia bristle-like.

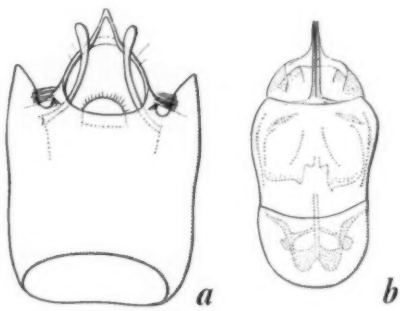

FIG. 3. *Saileriola sandakanensis* n. sp.: *a*, Ninth segment of abdomen of male, dorsal aspect; *b*, aedeagus.

HOLOTYPE: Male, Sandakan, Borneo (Baker). No. 63131 in United States National Museum.

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The authors wish to extend their sincere thanks to Dr. R. I. Sailer of the United States National Museum for allowing us to study this interesting species and to Dr. J. C. M. Carvalho of the Museo Nacional Brazil who originally noticed this insect in the collections of the United States National Museum.

REFERENCES

LESTON, D. 1953. Notes on the Ethiopian Pentatomoidea (Hemiptera): XVI. An acanthosomid from Angola, with remarks upon the status and morphology of Acanthosomidae Stal. *Cia. Diamant de Angola, Pubs. Cult.* 16: 123–132.

LESTON, D., J. G. PENDERGRAST, and T. R. E. SOUTHWOOD. 1954. Classification of the terrestrial Heteroptera (Geocorisae). *Nature* 174: 91–94.

TULLGREN, A. 1918. Zur Morphologie und Systematik der Hemipteren I. *Ent. Tidskr.* 39: 113–133.

YANG, WE-I. 1938. A new method for the classification of urostylid insects. *Fan. Mem. Inst. Biol., Bul.* (*Zool.*) 8: 35–48.

——— 1939. A revision of Chinese urostylid insects (Heteroptera). *Fan. Mem. Inst. Biol., Bul.* (*Zool.*) 9: 5–66.

The General Biology of *Balanus glandula* Darwin

HAROLD BARNES and MARGARET BARNES[1]

THE CIRRIPEDE, *Balanus glandula* Darwin, is a common intertidal barnacle on the Pacific coast of North America, ranging from the Aleutian Islands to the northern border of Mexico. It appears to occupy much the same niche as that of *B. balanoides* (L.) on the eastern side of North America and the coasts of Europe. There has been much work recently on the latter species and it seemed of great interest to compare the general biology and ecology of the two species. A preliminary study is here reported; it has been made possible by the courtesy of Dr. D. B. Quayle of the Provincial Shellfish Laboratory, Ladysmith, Vancouver Island, Canada, and Dr. R. J. Menzies (and later, Dr. K. M. Budge) of the Scripps Institution of Oceanography, La Jolla, California. We wish to thank them for sending regularly samples of preserved material at about monthly intervals over a period of some 18 months.

THE GENERAL DISTRIBUTION

B. glandula has been found in the intertidal zone from the Aleutian Islands (52°N. Lat.) to the northern border of Mexico (32°25′N. Lat.) (Darwin, 1854; Pilsbry, 1916). Such an extensive distribution has been confirmed by Cornwall (1925, 1951, and 1955*b*). Ricketts and Calvin (1939) state that it is found at Ensenada (32°N. Lat.) and, although they admit that it may occur farther south, this appears to be about the southern limit, for Henry (1941) failed to find it in parts of Lower California and Mexico. Living under widely varying conditions of environment, this cirripede is found on wave-swept cliffs (35 miles south of the Mexican border) where all around *Chthamalus* sp. has become the dominant species on the open outer coast and in the quiet bays of enclosed water such as Puget Sound; it may thrive under conditions of poor circulation, low salinity, and slight wave action. At Pacific Grove, while absent from regions of excessively high surf on the open coast (the suggestion has even been made that this is due to the inability of the cyprids to settle under these conditions) it occurs at the uppermost levels of the shore. In more protected areas *B. glandula* is found at a level somewhat below high tide. It is often associated with *Acmaea digitalis* Eschscholtz (= *A. persona*) and *Littorina planaxis* (Nuttall). Although usually occupying a higher level than *Balanus cariosus* (Pallas), when the two are intermingled *B. glandula* may often be found attached to the former rather than to bare rock.

In the Puget Sound area the species appears to thrive best in places which differ markedly from those where it is found on the open coast (Shelford, 1930; Towler, 1930; Worley, 1930; Rice, 1930; Henry, 1940). According to these authors the barnacle is rarely crowded in this region, only a small number of elongated individuals being found; it is most abundant in the salinity range 26–30 parts per thousand and in a zone some three metres above low tide level. Worley (1930) has suggested that temperature is important in regulating the local distribution since the entrance of freshwater into Puget Sound during the summer not only reduces the salinity but also increases the temperature. Conse-

[1] The Marine Station, Millport, Scotland. Manuscript received December 2, 1955.

quently, regions of lower salinity have a higher sea temperature (see also Rice, 1930). In the summer months the surface sea temperature in open water and where wave action is heavy ranges from 9–11°C., whereas in enclosed bays and areas protected from wave action it may reach 11–20°C. during the same period (Shelford and Towler, 1925). The greater temperature during the summer months in enclosed bays may also be responsible for the restriction of *B. glandula*, in such places, to the lower levels of the shore. *B. cariosus* is less resistant to reduced salinity, high temperatures, and products of decomposition than *B. glandula*, so that the latter penetrates farther into the brackish water.

B. glandula appears to have a variety of forms depending on its environment, and Pilsbry (1916) takes San Diego as a typical locality and discusses the variety of shapes which occur; conic or convexly conic with small aperture, at San Diego; more cylindrical, much less ribbed (some not at all) and with larger aperture, at San Francisco; a mixture of strongly ribbed, typical individuals and weakly ribbed, cylindrical ones with large aperture in the Puget Sound region. He describes shorter, obliquely conic forms on elongated, columnar individuals from Union Bay, Baynes Sound, British Columbia, and from Sitka both ribbed conic and smooth short, cylindrical forms; his Unalaska specimens were strongly ribbed with wider radii than the California type. Specimens from Atka, although similar to those from Unalaska in the walls, differed from all other types in their opercular valves. Barnacles are extremely plastic as regards their growth form, varying widely according to the conditions of the environment (Barnes and Powell, 1950) and without further work it may be doubted whether these varieties are subspecies or even local races; this has been confirmed by Henry (1942). The individuals used for this present work were similar to those of Pilsbry's typical locality; many examples of the "varieties" were, however, encountered. Cornwall (1955*a*) refers to *B. glandula* as small, 10–18 mm. in diameter in uncrowded specimens and height a little more than half the diameter, and suggests that its extremely variable appearance is perhaps due to its wide range of habitat.

In contrast to some other common barnacles of the western coast of America, for example *B. cariosus* and *Chthamalus dalli* Pilsbry, *B. glandula* does not appear to be present in Japanese waters (Hiro, 1935).

MATERIAL AND METHODS

The collections were made at about monthly intervals from the shore at Ladysmith, Vancouver Island, and from the pier of the Scripps Institution of Oceanography at La Jolla.

At Ladysmith two series of samples were taken: one, for the examination of the gonads, from the intertidal zone between the 2 and 6 foot levels, was preserved in formalin and a second, which was preserved dry and used for size measurements, from the 5 foot level. At Ladysmith lower high water is + 9 feet and higher high water is 11–13 feet with a tidal range of some 16 feet. The samples from La Jolla were taken from the south side of the pier of Scripps Institution at a point where *B. glandula* forms a zone about 0.4 metre wide. The height of low water is 0.9 feet and the mean tidal range is 3.6 feet (Anon, 1953).

The state of the gonads was examined on about 50 individuals from each sample, the stage of development and colour of the ovaries or egg masses being noted as well as the condition of the male organs. The carino-rostral diameter of up to 150 animals was measured in each sample and an attempt made to separate the year classes by plotting cumulative percentages on arithmetic probability paper. When a new spat fall was well defined and could be clearly followed through several samples it was measured separately. The smaller animals were measured under a binocular microscope with a scaled ocular; for the larger animals calipers were used.

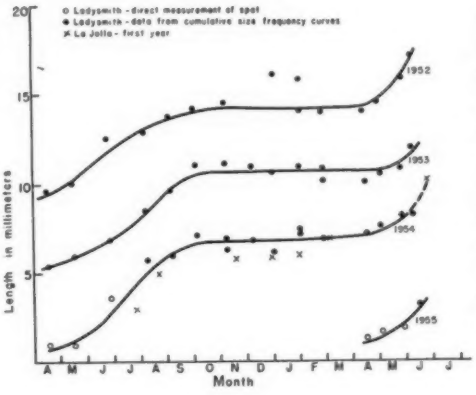
o Ladysmith - direct measurement of spat
● Ladysmith - data from cumulative size frequency curves
× La Jolla - first year
1952
1953
1954
1955
Length in millimeters
Month
A M J J A S O N D J F M A M J J

FIG. 1. Growth rate of *Balanus glandula* at Ladysmith, Vancouver Island, and at La Jolla, California.

GROWTH RATE

The cumulative frequency curves showed the presence of several distinct populations in each collection and, although the spread of any year group was considerable, the first three year groups could be separated with reasonable certainty (the subsidiary broods make little impression on the main populations). It is evident that growth takes place largely during the spring and summer months with relatively little or no growth in the winter. This is true both at Ladysmith and La Jolla, although at the latter there is some indication of growth during the winter months particularly of the first season. On the Ladysmith samples it was quite possible to follow directly from the spat fall the first season's growth; from a mean size of 1.2 mm. in April, a size of 7.0 mm. was reached by the end of the summer. At the end of the second season the mean size was some 11.0 mm. and it became 16.0 mm. at the end of the third season. Beyond this point deformities and crowding make the measurement less certain but it would seem that individuals reach a size of about 21 mm.

An examination of Figure 1 suggests that the growth rate at La Jolla is somewhat slower than at Ladysmith; the mean size of the first year group tends to fall below that value for Ladysmith. Too much significance should not be attached to this possibility since marked individuals were not measured.

On one occasion a sample was available from Ladysmith that had been maintained at a very low tidal level. The growth rate was double that of the animals from the higher regions of the tidal zone, doubtless as a result of the greater periods of immersion at the lower levels (see Barnes and Powell, 1953).

BREEDING

The conditions of the ovaries or egg masses throughout the year are shown in Tables 1 (Ladysmith) and 3 (La Jolla) which give percentage of individuals at any particular stage of development.

At Ladysmith all the animals contained well-developed unfertilised creamy-yellow ovaries in the midwinter sample of December 8. At the same time the vesiculae seminales were very prominent and the penes long and turgid. By January 3 some 20 per cent contained fertilised eggs present as firm light-yellow masses in the mantle cavity. On February 1 all individuals contained fertilised eggs, with 60 per cent in possession of eyed nauplii. It is clear that fertilisation probably begins in December and extends into January perhaps being a little less synchronous throughout the population than in some other species (Barnes and Barnes, 1954; Crisp, 1954; and Barnes, in press). As the embryos developed, the gorged appearance of the male organs disappeared, the seminal vesicles shrinking and becoming relatively inconspicuous; the penis became less turgid but there was no sign of gross regression.

By the end of February virtually the whole population contained eyed nauplii and these had been almost completely discharged by mid-April. Release into the plankton of the major brood takes place, therefore, in March. This gives a period of probably 2 months as the nearest estimate that can be made for the

TABLE 1

CONDITION OF THE OVARIES OF SPECIMENS OF *Balanus glandula* TAKEN AT LADYSMITH THROUGHOUT THE YEAR

DATE	PERCENTAGE OF SPECIMENS			
	Eggs unfertilised, not well defined	Eggs unfertilised, well defined, creamy yellow	Eggs fertilised, yellow	Eyed nauplii present, yellowish brown to brown
15/ 4/54	51	11	27	11
15/ 5/54	42	43		15
2/ 6/54	50	50		
30/ 6/54	← 100 →			
10/ 8/54	26	68	4	2
7/ 9/54	15	75	5	5
6/10/54	← 100 →			
10/11/54	20	80		
8/12/54		100		
3/ 1/55		80	20	
1/ 2/55			40	60
27/ 2/55			4	96
15/ 4/55	71	22		7
5/ 5/55	30	55	10	5
7/ 6/55	50	50		

period of incubation in the mantle cavity. However, some liberation of nauplii must take place later since eyed nauplii were found up to late May, but this is in only a small fraction of the population. Redevelopment of the ovary takes place, in part, almost as soon as the major brood is released and it is quite evident that small broods are produced later in the year, for a small proportion of specimens were found with eyed nauplii as late as August and September.

Table 2 gives notes supplied by Dr. Quayle on the appearance of the shore settlement of *B. glandula* based on observations made during the course of his own work. These, taken in conjunction with the estimated dates of release given above indicate a planktonic life of about 1 month; they also confirm that the major settlement takes place in the spring with some sporadic liberation into the early summer. His records of the presence of nauplii in the plankton on August 27 as well as September 20 in 1951 also confirm the production of a small autumn brood.

These results also accord with the observations of Johnson (1932) at Friday Harbor, somewhat to the south of Ladysmith; he found barnacle larvae (species not stated) to first appear in the plankton in February with the maximum number in March and April. In a later paper with R. C. Miller (1935) he also refers to an autumn outburst of *B. glandula*.

The data in Table 3 indicate that at La Jolla the major portion of the sample was full of ripe unfertilised eggs by the end of September and early October. Fertilising began either in October or the early part of November and was complete by December; by the end of this month the greater proportion of the sample contained eyed nauplii, the large majority of which must have been released by the end of January. It is also evident that redevelopment of the ovaries takes place straight after shedding and that smaller broods are developed in March, April, and May inasmuch as up to 24 per cent of the individuals had eyed nauplii during this period. No breeding takes place after May, the ovaries gradually filling up to be ripe again by the end of September.

SIZE OF EGGS AND EGG PRODUCTION

The size of a number of egg cases with well-developed nauplii were measured. They

had a mean length of 0.22 mm. and a mean width of 0.125 mm. Fully developed eggs released from the ovarian tubules before they were fertilised had a diameter of 0.146 mm.

In order to measure the productivity the number of embryos in the egg masses of ripe individuals was counted. Figure 2 shows a plot of the number of nauplii against the cube of the length of the adult. There is a linear relation suggesting, as might be expected, that the production is a function of the volume as has been found for other species (Barnes, 1953; Barnes and Barnes, 1954). The slope of the line is different, however, from that for the other species. Apart from any intrinsic differences in productivity the relation between volume and length cubed will vary from species to species.

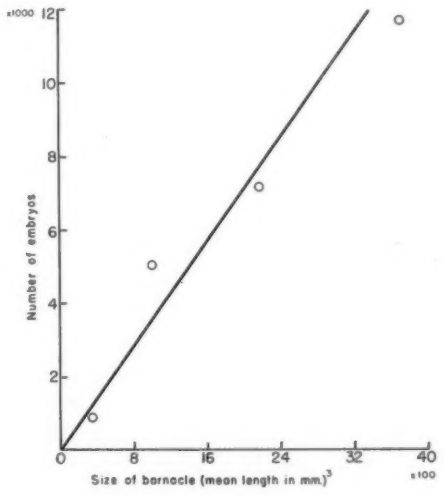

FIG. 2. Relation between number of embryos in the egg masses of ripe *B. glandula* and volume (cube of the length) of the adult.

DISCUSSION

Temperature data (means for several years) for La Jolla (kindly supplied by the Scripps Institution) and for protected areas in the neighbourhood of Ladysmith (see Hollister, 1954) together with values at Ladysmith for 1954, are given in Table 4.

At La Jolla the major brood of nauplii is fertilised in November, with a mean sea temperature of 16°–17°C., being released in January when the temperature (14°C.) is close to the minimum for the year. Smaller broods are produced up to May but none during the summer and autumn. Breeding only takes place when the temperature is below about

TABLE 2

OBSERVATIONS ON THE SETTLEMENT OF *Balanus glandula* AT LADYSMITH

YEAR	MAIN SETTLEMENT AT LADYSMITH	REMARKS
1949	April 1	Sooke—May 16; lighter settlement at Ladysmith in July
1950	April 19	Intermittent settling until May 20; plankton still contained some nauplii and cyprids on May 22
1951		Nauplii in plankton from mid February to mid April; at intervals, May 9–21, July 31, August 27, September 20, none later
1952	About March 21	Week later at Ucluelet on west coast of Vancouver Island
1953	April 15	Light settlement at Comox (100 miles north of Ladysmith) on April 14
1954	April 1–6	Light settlement about June 1
1955	April 10, light, April 20, main set, lasting until end of April	At Crofton (8 miles south of Ladysmith) set during first week of May

TABLE 3

CONDITION OF THE OVARIES OF SPECIMENS OF *Balanus glandula* TAKEN AT LA JOLLA THROUGHOUT THE YEAR

DATE	PERCENTAGE OF SPECIMENS			
	Eggs unfertilised, not well defined	Eggs unfertilised, well defined, creamy yellow	Eggs fertilised, yellow	Eyed nauplii present yellowish brown to brown
20/ 7/54	24	76		
23/ 8/54	8	92		
23/ 9/54	15	85		
22/11/54		61	24	15
29/12/54			17	83
31/ 1/55		45	45	10
3/ 3/55		40	36	24
20/ 5/55		79		21
25/ 6/55	33	67		

TABLE 4

TEMPERATURE DATA FOR LA JOLLA AND LADYSMITH

	LA JOLLA (mean of 27 years)	LADYSMITH REGION 1952	LADYSMITH, 3 FEET BELOW SURFACE AND 50 YARDS FROM SAMPLING POSITION, 1954
January	14.0	6.2	4.7
February	13.9	6.1	5.9
March	14.5	6.7	7.0
April	15.5	8.2	8.7
May	17.2	10.9	13.0
June	18.6	13.1	14.7
July	19.8	15.4	18.2
August	20.6	15.1	18.1
September	19.2	13.4	14.5
October	18.0	12.1	11.4
November	16.3	8.8	9.2
December	15.1	7.7	7.1
Average	16.9	10.3	11.0
Maximum	20.6	15.4	18.2
Minimum	13.9	6.1	4.7
Range	6.7	9.3	13.5

17°C. At Ladysmith the major brood is fertilised and indeed released during the colder parts of the year when sea temperatures are between 6° and 8°C. However, there is an autumn brood, shed in August and September, which may have been fertilised in June and July when the temperature is again about 17°C. Bearing in mind the northward extension of the species the evidence suggests that the southern limit is determined by minimum temperatures of the order of 17°C., a lower temperature being required for breeding. When the effects of competition with warm water species are taken into account this is in agreement with the fact that, as far as can be ascertained, temperatures at Ensenada, presumably taken offshore (U. S. Navy Hydrographic Office, 1944), are almost uniform throughout the year, never falling below a mean monthly value of about 15°C.

The upper temperature limit for breeding which takes place in the coldest months of the year is in agreement with a wide distribution northwards. However, if as suggested the

temperature barrier is at 16°–17°C., temperature conditions do not limit the breeding to the colder months of the year at Ladysmith and regions farther to the north; the breeding rhythm is tied to some other factors.

In *B. balanoides*, a boreo-arctic species, breeding appears to be determined by a temperature barrier at about 8°C. so that the southern limit is determined by the southern limit of the mean winter isotherm of 8°C. (Hutchins, 1947). It is found, therefore, farther south on the eastern seaboard of North America than on the coast of Europe as a result of the cold currents coming down the former coast. *B. glandula*, if a boreo-arctic species, seems to have raised the temperature barrier much higher so that it extends farther to the south on the western coast of America. It is of interest to note, however, the resemblance to *B. crenatus* which even near the southern limits of its distribution produces a second brood in the autumn of the year although it is considered to be an arctic species —more so than *B. balanoides*.

REFERENCES

ANONYMOUS. 1953. *Tide Tables, West Coast.* U. S. Dept. Commerce, Coast and Geodetic Survey.

BARNES, H. 1953. Size variations in the cyprids of some common barnacles. *Mar. Biol. Assoc. U. K., Jour.* 32: 297–304.

——— In press. *Balanus balanoides* (L.) in the Firth of Clyde: the development and annual variation of the larval population and the causative factors.

BARNES, H., and M. BARNES. 1954. The general biology of *Balanus balanus* (L.) Da Costa. *Oikos* 5: 63–76.

BARNES, H., and H. T. POWELL. 1950. The development, general morphology and subsequent elimination of barnacle populations, *Balanus crenatus* and *B. balanoides* after a heavy initial settlement. *Jour. Anim. Ecol.* 19: 175–179.

——— and ——— 1953. The growth of *Balanus balanoides* (L.) and *B. crenatus* Brug. under varying conditions of submersion. *Mar. Biol. Assoc. U. K., Jour.* 32: 107–128.

CORNWALL, I. E. 1925. A review of the cirripedia of the coast of British Columbia, with glossary and key to genera and species. *Contrib. Canad. Biol.* (*N.S.*) 2: 471–502.

——— 1951. The barnacles of California (Cirripedia). *Wasmann Jour. Biol.* 9: 311–346.

——— 1955*a*. The barnacles of British Columbia. *Brit. Columbia Department of Education Handbook.* No. 7, 69 pp. Provincial Museum, Vancouver.

——— 1955*b*. Cirripedia. *Canadian Pacific Fauna.* 10. Arthropoda. 10 e. 49 pp. Fisheries Research Board of Canada, Ottawa.

CRISP, D. J. 1954. The breeding of *Balanus porcatus* (Da Costa) in the Irish Sea. *Mar. Biol. Assoc. U. K., Jour.* 33: 473–496.

DARWIN, C. R. 1854. *A monograph on the subclass Cirripedia with figures of all the species.* Vol. 2. The Balanidae. viii + 684 pp., 30 pls. Ray Society, London.

HENRY, D. P. 1940. The cirripedia of Puget Sound with a key to the species. *Wash.* [*State*] *Univ., Pubs. Oceanog.* 4: 1–48.

——— 1941. Notes on some sessile barnacles from Lower California and the west coast of Mexico. *New England Zool. Club, Proc.* 18: 99–106.

——— 1942. Studies on the sessile barnacles of the Pacific coast of North America. *Wash.* [*State*] *Univ., Pubs. Oceanog.* 4: 95–134.

HIRO, F. 1935. The fauna of Akkeshi Bay. II. Cirripedia. *Hokkaido Univ., Jour. Fac. Sci.* Ser. VI Zoology 4: 213–229.

HOLLISTER, H. J. 1954. What was the temperature of the sea water on the British Columbia coast in 1952? *Canada, Fish. Res. Bd., Prog. Rpt. of Pacific Coast Stations* No. 98: 6–9.

HUTCHINS, L. W. 1947. The bases for temperature zonation in geographical distribution. *Ecol. Monog.* 17: 325–335.

JOHNSON, M. W. 1932. Seasonal distribution of plankton at Friday Harbor, Washington. *Wash.* [*State*] *Univ., Pubs. Oceanog.* 1: 1–38.

JOHNSON, M. W., and R. C. MILLER. 1935. The seasonal settlement of shipworms, barnacles and other wharf-pile organisms at Friday Harbor, Washington. *Wash.* [*State*] *Univ., Pubs. Oceanog.* 2: 1–18.

PILSBRY, H. A. 1916. The sessile barnacles (Cirripedia) contained in the collections of the U. S. National Museum; including a monograph of the American species. *U. S. Natl. Mus., Bul.* 93: 1–366.

RICE, L. 1930. Peculiarities in the distribution of barnacles in communities and their probable causes. *Wash.* [*State*] *Univ., Puget Sound Biol. Sta., Pubs.* 7: 249–257.

RICKETTS, E. F., and J. CALVIN. 1939. Between Pacific Tides. xxii + 320 pp. Stanford University Press, Stanford University.

SHELFORD, V. E. 1930. Geographic extent and succession in Pacific North American intertidal (*Balanus*) communities. *Wash.* [*State*] *Univ., Puget Sound Biol. Sta., Pubs.* 7: 217–224.

SHELFORD, V. E., and E. D. TOWLER. 1925. Animal communities of the San Juan Channel and adjacent areas. *Wash.* [*State*] *Univ., Puget Sound Biol. Sta., Pubs.* 5: 33–73.

TOWLER, E. D. 1930. An analysis of intertidal communities of the San Juan Archipelago. *Wash.* [*State*] *Univ., Puget Sound Biol. Sta., Pubs.* 7: 225–232.

U. S. NAVY HYDROGRAPHIC OFFICE. 1944. *World atlas of sea surface temperatures.* H. O. No. 225, 2nd Ed., reprinted, 1948. Hydrographic Office U. S. Navy, Washington.

WORLEY, L. G. 1930. Correlation between salinity, size, and abundance of barnacles. *Wash.* [*State*] *Univ., Puget Sound Biol. Sta., Pubs.* 7: 233–240.

Observations on Two Species of *Liagora* (Rhodophyta)[1]

T. V. Desikachary[2]

Although the ontogeny of the cystocarp has been studied in a number of species of the nemalionalean genus *Liagora* (Butters, 1911; Børgesen, 1915–20, 1927; Kylin, 1930; Yamada, 1938; Levring, 1941; Abbott, 1945), gaps still exist in our knowledge of the development of this structure. Thus, little precise information is at hand concerning the place of origin of the so-called involucral filaments and as regards the presence or absence of a fusion-cell in the mature cystocarp of certain species (see Papenfuss, 1946: 433, 434). The present account is based upon a study of two Hawaiian species, *L. maxima* Butters and *L. Papenfussii* Abbott, material of which was kindly placed at the disposal of the writer by Professor Papenfuss.

Liagora maxima

Described by Butters (1911) from the Hawaiian Islands, this species was again reported by Abbott (1945). The material studied by the writer was collected by Papenfuss on the Island of Oahu (1.8 miles west of Nanakuli) on May 16, 1941.

Structure of thallus: The general habit and structure of *Liagora maxima* have been well described by both Butters and Abbott. Although the thallus varies greatly in length, some specimens may attain a height of as much as 40 cm., which marks this species as one of the largest in the genus. The plants are very much calcified. The main branches arise at or near the base and constitute percurrent axes from which issue branches of limited growth. The main axes and their branches are composed of a central core of compact, vertical filaments (the medulla) from which are produced radially directed assimilatory laterals (the cortex). The lateral filaments are repeatedly dichotomously branched—up to the sixth order (Fig. 1*a*). The length of the cells of these filaments and the distance between the dichotomies gradually diminish toward the surface of the thallus. In younger parts the assimilatory filaments often terminate in long hairs.

Reproduction: *Liagora maxima* is dioecious. The spermatangia are borne in clusters at the extremities of the assimilatory filaments (Fig. 1*b*, *e*, *f*). At the tips of these filaments from one to six spermatangial mother cells are formed, each of which produces one to three spermatangia.

The carpogonial branches are produced laterally on the assimilatory filaments (Figs. 1*c*, *d*, *g*, 2 *d*) and usually in the younger parts of the thallus—at times even before the assimilatory filaments are fully developed (Fig. 1*d*, *g*). They are generally formed on the cells behind the third or fourth furcation and are characteristically composed of three cells (Figs. 1*d*, 2*a*, *b*, *d*, *h*) but are sometimes four-celled. The mature carpogonium has a long trichogyne which projects beyond the periphery of the thallus. In a few instances spermatia were seen attached to the tip of the trichogyne (Fig. 2*d*).

After fertilization the content of the trichogyne is separated from that of the carpogonium proper (Fig. 2*a*, *b*, *h*). The carpogonium then divides by a transverse septum, forming a stalk cell and a gonimoblast initial (Figs. 2*e*, 3*e*) from which is produced the gonimoblast (Fig. 2*c*). The gonimoblast con-

[1] This study was carried out during the tenure of a Fulbright award, for which the writer is very grateful. Thanks are due Professor George F. Papenfuss of the University of California, Berkeley, for his kind guidance during the investigation. Manuscript received November 22, 1955.

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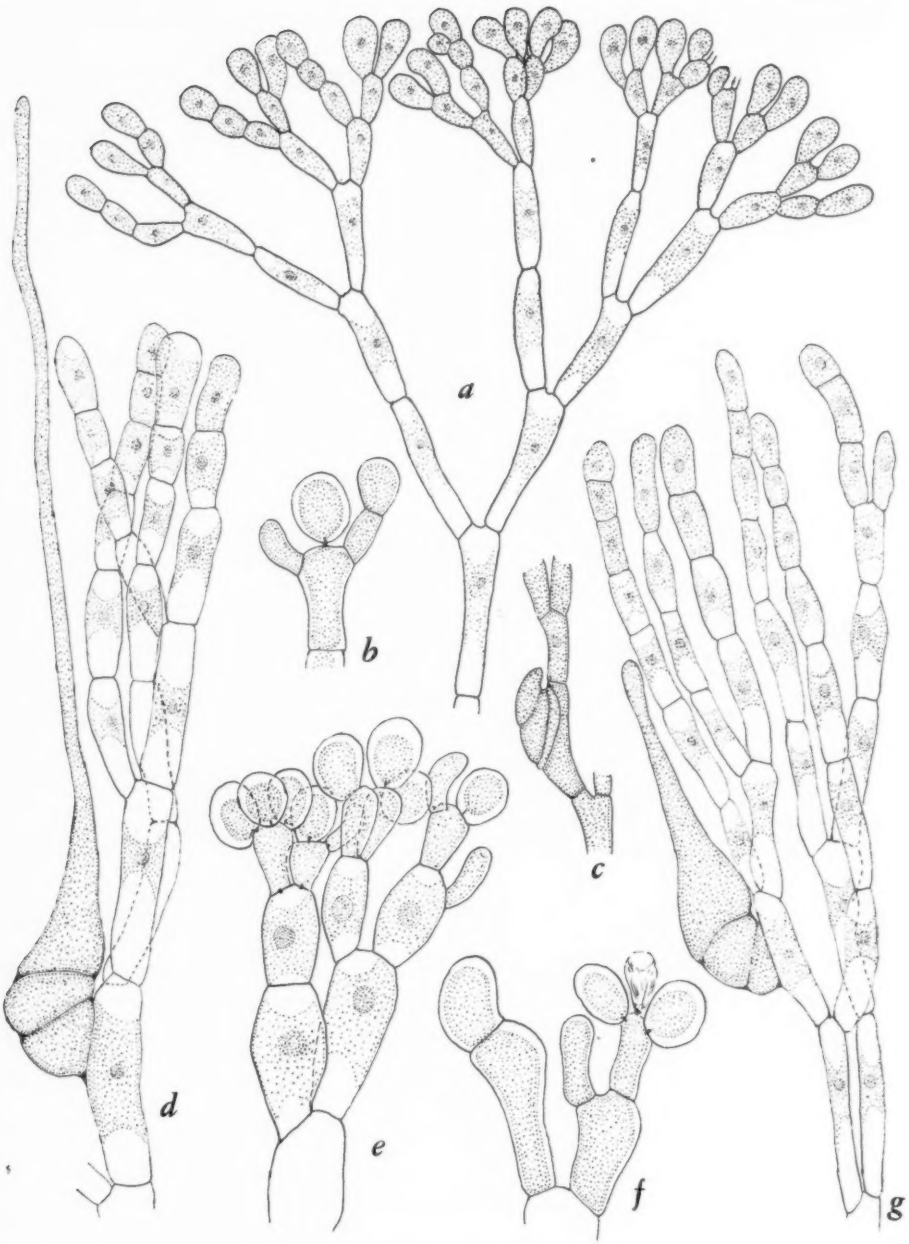

FIG. 1. *Liagora maxima* Butters. *a*, Assimilatory filament, ×553; *b*, *e*, *f*, antheridia, ×2266; *c*, *d*, *g*, carpogonial branches, ×1133.

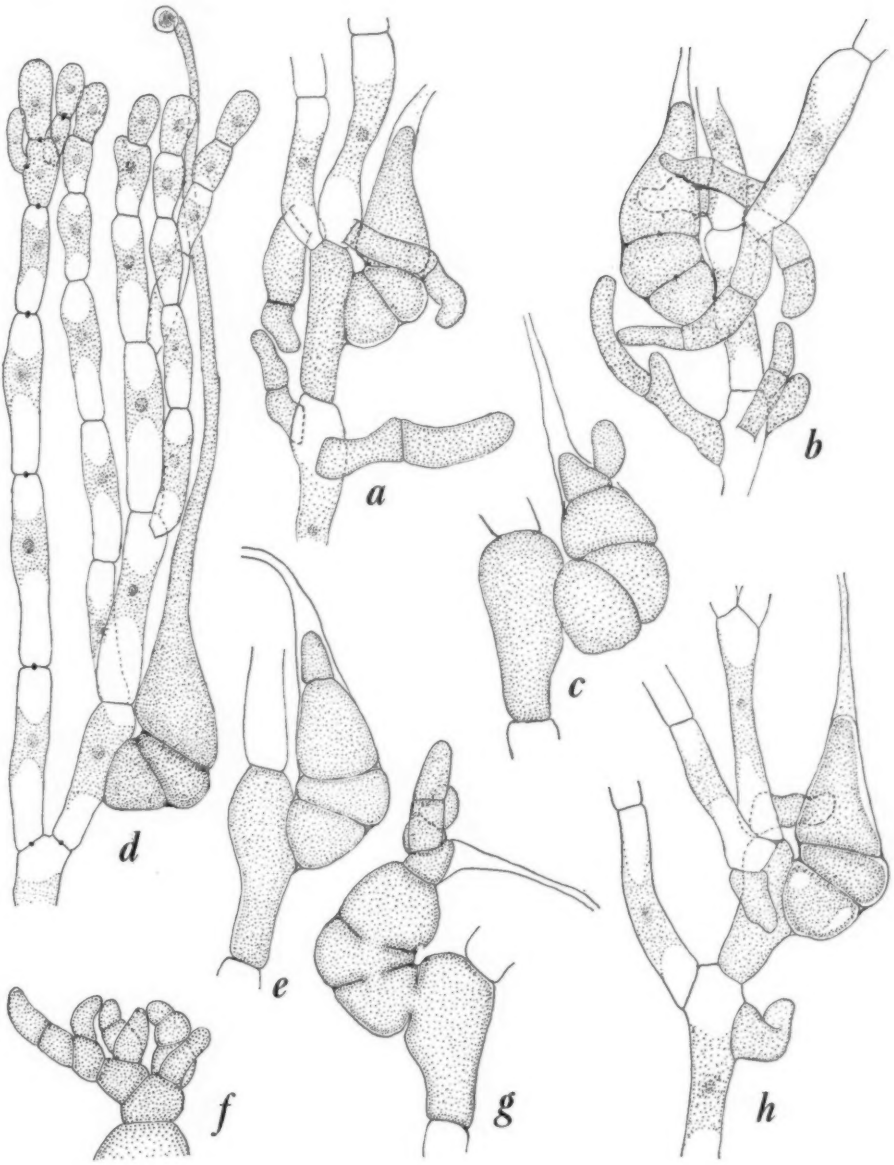

FIG. 2. *Liagora maxima* Butters. *a–c*, *e–h*, Post fertilization stages; *d*, carpogonial branch showing trichogyne with attached spermatium. All ×1020.

sists of branched filaments (Figs. 2*f*, *g*, 3*a–c*) which form terminal carposporangia (Fig. 3*c*, *d*).

Soon after fertilization of the carpogonium, involucral filaments are initiated. These filaments are formed by the vegetative cells above and below the supporting cell and rarely also by other vegetative cells in the neighborhood of the carpogonial branch (Fig. 2*a*, *b*, *h*). The involucral filaments grow up and around the developing gonimoblast and are very much branched (Fig. 3*a*). They are generally narrower than the gonimoblast filaments and have a dense cytoplasmic content. Later, as the development of the gonimoblast advances, vacuolization of the cells of the involucral filaments becomes evident and the filaments ultimately lose most of their contents and become colorless (Fig. 3*c*).

Concurrently with the formation of the gonimoblast, changes occur in the cells of the carpogonial branch. These cells acquire a dense content and increase in size, often becoming two or three times larger than they originally were (Fig. 2*c*, *g*). The protoplasmic connections between the cells gradually widen, resulting finally in the establishment of a large fusion-cell, comprised of the supporting cell, the cells of the carpogonial branch, and the stalk cell (Figs. 2*g*, 3*b*, *f*). The gonimoblast initial is not incorporated in the fusion-cell. At first, the fusion-cell has a dense content but later, as the gonimoblast continues growth, the content gradually becomes vacuolated and less dense.

The account of the development of the gonimoblast of *Liagora maxima* presented here is, in some respects, at variance with the description as given by Abbott (1945). According to her the carpogonial branch is four-celled when mature. In the present investigation, the mature carpogonial branches were almost always observed to be three-celled—only rarely do they become four-celled. This is the only species of *Liagora*, in addition to *L. viscida* (Kylin, 1930), in which a fusion-cell has been observed. According to Abbott the involucral filaments are formed from the supporting cell, but in the present study they were observed to be produced by the vegetative cells above and below the supporting cell—never from the supporting cell.

Liagora Papenfussii

This species was described by Abbott (1945) from material collected by Papenfuss on the Island of Oahu. The writer's observations are based on part of the same material. *Liagora Papenfussii* is the fourth of the known species of *Liagora* in which the gonimoblast has been observed to produce tetrasporangia instead of carposporangia (i.e., monosporangia). The other three species are *L. tetrasporifera* Børgesen (1927), Japanese specimens of *L. pinnata* Harvey (Yamada, 1938), and *L. brachyclada* Decaisne (Levring, 1941). Børgesen (1927) and Kylin (1930) have made detailed studies of *L. tetrasporifera*. In its development this species differs in some respects from *L. viscida* as observed by Kylin (1930). A short account of the main features of *L. Papenfussii* follows. The author's observations on this species agree entirely with those of Abbott and point to the distinctness of the species.

STRUCTURE OF THALLUS: The thallus is composed of a core of large axial filaments from which issue radially directed assimilatory filaments. These lateral filaments are divided four to six times, the distance between the branches being quite short (Fig. 4*a*, *b*). The cells are short and barrel-shaped toward the axial part of the thallus and decrease in length toward the periphery. They have a thick wall and are joined by conspicuous cytoplasmic connections. In the younger parts of the thallus the assimilatory filaments often terminate in short hairs.

REPRODUCTION: *Liagora Papenfussii* is monoecious. The spermatangia are produced in clusters at the tips of the assimilatory filaments. From the terminal cell of an assimilatory filament two to three spermatangial mother cells are generally cut off, each of

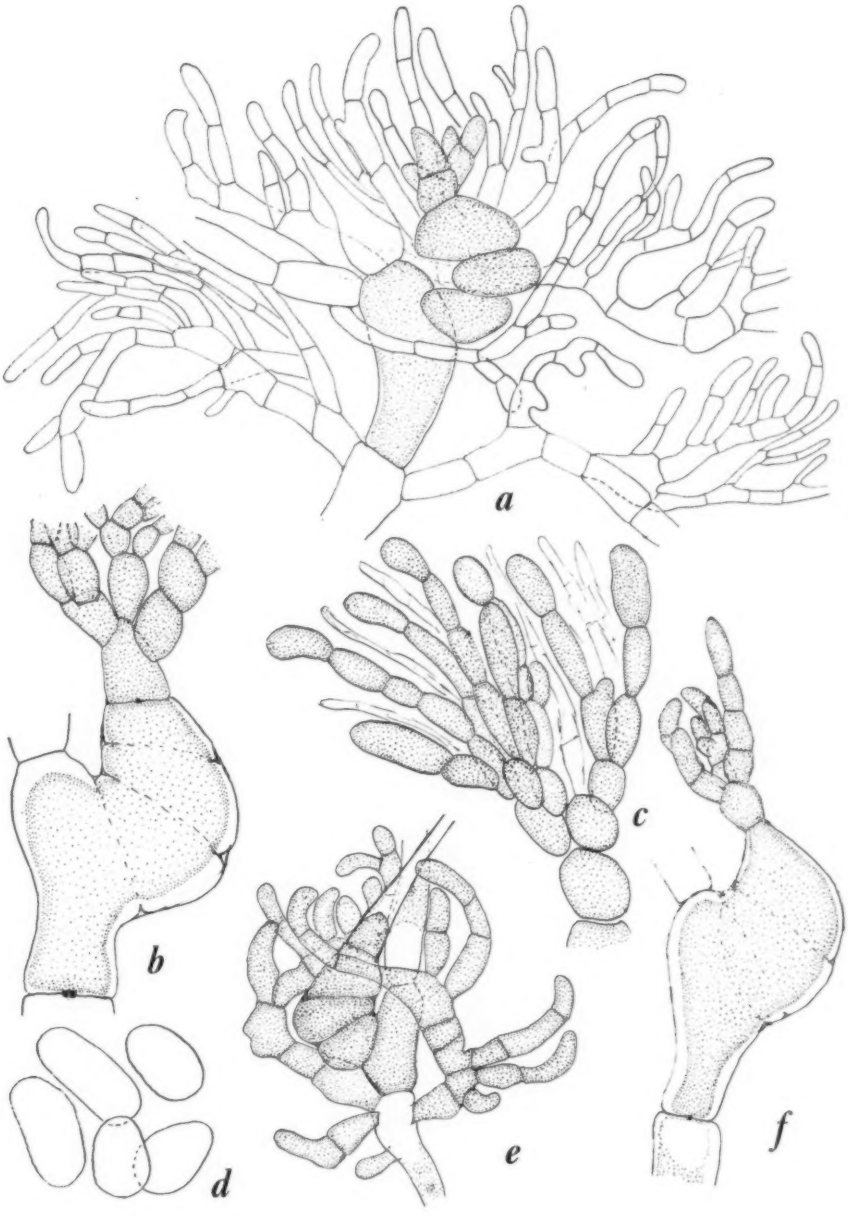

FIG. 3. *Liagora maxima* Butters. *a–c, e, f,* Post fertilization stages; *d,* carpospores. *a,* ×605; *b–f,* ×935.

which gives rise to two or three spermatangia (Fig. 4*a*, *b*).

The carpogonial branches are produced as lateral accessory branches on the assimilatory filaments and usually behind the third or fourth furcation of these filaments. The carpogonial branch initial is cut off as a lens-shaped cell (Fig. 4*e*). By repeated division it gives rise to a four-celled branch, the terminal cell of which is the carpogonium (Fig. 4*c*, *d*, *f*, *g*). In the mature condition the carpogonium has a long trichogyne which extends to the surface of the thallus (Fig. 5*a*).

After fertilization the cytoplasm of the

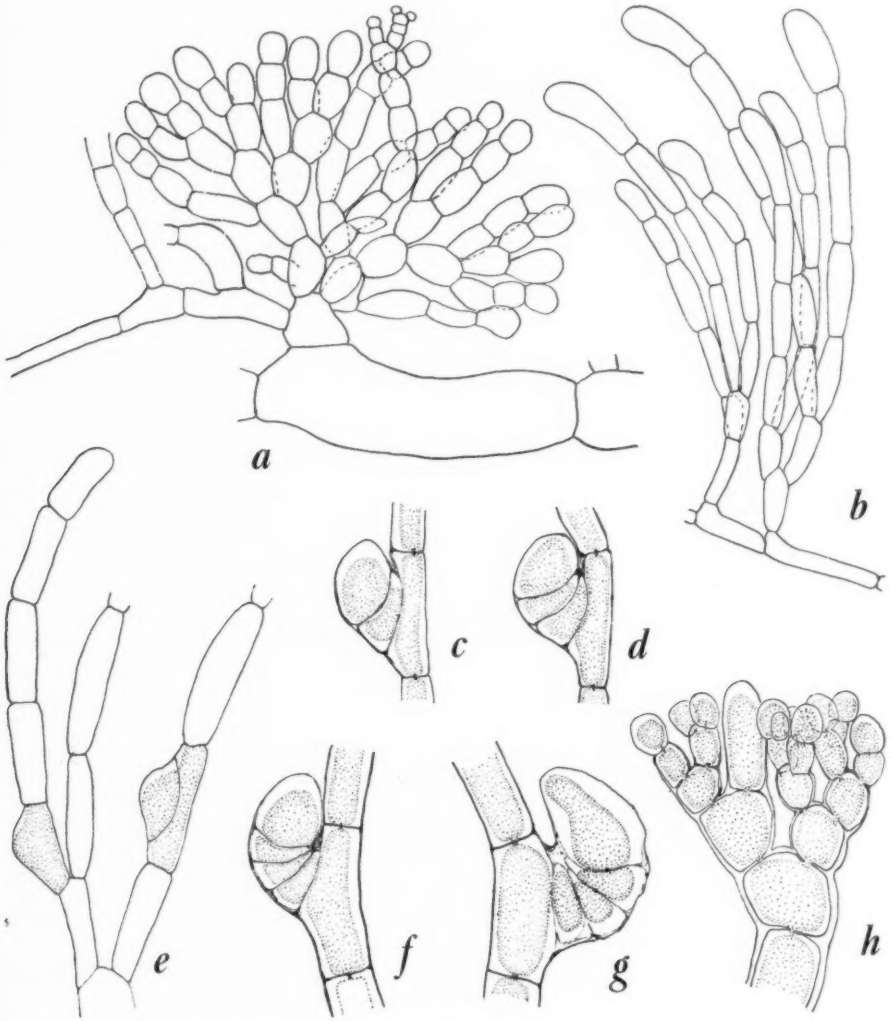

FIG. 4. *Liagora Papenfussii* Abbott. *a*, *b*, Old and young assimilatory branches, respectively; *c–g*, development of carpogonial branches; *h*, antheridia. *a*, ×270; *b*, ×660; *c–h*, ×1020.

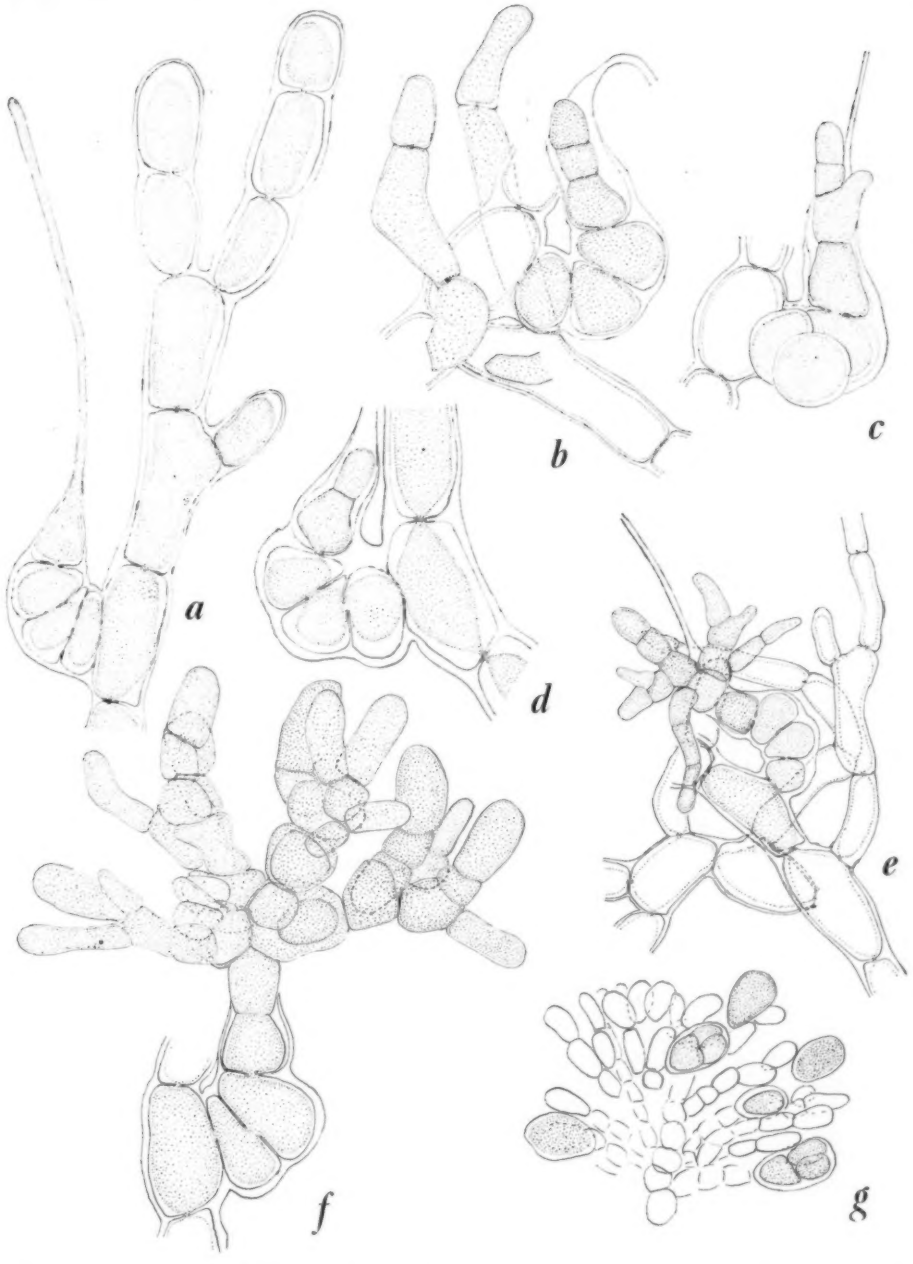

FIG. 5. *Liagora Papenfussii* Abbott. *a–f*, Post fertilization stages; *g*, old cystocarp showing tetrasporangia. *a–d*, *f*, ×765; *e*, ×495; *g*, ×373.

trichogyne is separated from that of the carpogonium proper and the carpogonium then divides by a transverse wall (Fig. 5*d*) into a stalk cell and the gonimoblast initial. The gonimoblast initial gives rise to a much-branched gonimoblast (Fig. 5*b*, *c*, *e*, *f*). The gonimoblast filaments form terminal tetrasporangia (Fig. 5*g*).

A fusion-cell is apparently not formed in this species. At times, however, a distinct enlargement of the cytoplasmic connections occurs (Fig. 5*d*, *f*).

Only a slight development of involucral filaments occurs (Fig. 5*b*, *e*). A few filaments are formed from the vegetative cells above the supporting cell and occasionally from cells of the other vegetative filaments near the supporting cell.

DISCUSSION AND SUMMARY

The observations on *Liagora maxima* and *L. Papenfussii* have contributed to an elucidation of two points, in particular, in the development of the cystocarp in *Liagora*.

Previously the occurrence of a fusion-cell in the cystocarp of *Liagora* has been reported only in *L. viscida* (Kylin, 1930). The observation of such a cell in *L. maxima* shows that this is a condition which may occur also in some of the other species of *Liagora*. An investigation of the numerous species of this genus with respect to this feature would be of interest.

Involucral filaments have been reported as present in the cystocarp of a number of species of *Liagora*. In most instances authors have neglected to state from which cells these filaments are derived. It is also not possible to obtain this information from the published illustrations. According to Kylin (1930: 9), involucral filaments are not produced in *L. viscida*. Hamel (1930: 76), however, states that such filaments are present in this species and that they are formed by the cells of the carpogonial branch. Abbott (1945: 148) described the involucral filaments as issuing from the supporting cell in *L. maxima*. The present writer's observations show that in the latter species they are produced by the vegetative cells above and below the supporting cell and rarely also by other vegetative cells in the vicinity of the carpogonial branch. Precise information on the place of origin of these filaments in the various species of *Liagora* in which they occur is highly desirable.

REFERENCES

ABBOTT, ISABELLA A. 1945. The genus *Liagora* (Rhodophyceae) in Hawaii. *Bernice P. Bishop Mus., Occas. Papers* 18: 145–169, 16 figs.

BØRGESEN, F. 1915–1920. The marine algae of the Danish West Indies. Part 3. Rhodophyceae. *Dansk Bot. Arkiv.* 3: 1–498 + index of 6 pp., 435 figs.

——— 1927. Marine algae from the Canary Islands . . . III. Rhodophyceae Part 1, Bangiales and Nemalionales. *K. Danske Vidensk. Selsk., Biol. Meddel.* 6(6): 97 pp., 49 figs.

BUTTERS, F. K. 1911. Notes on the species of *Liagora* and *Galaxaura* of the central Pacific. *Minn. Bot. Studies* 4: 161–184, pl. 24.

HAMEL, G. 1930. Floridées de France VI. *Rev. Algologique* 5: 61–109, figs. 41–59.

KYLIN, H. 1930. Über die Entwicklungsgeschichte der Florideen. *Lunds Univ. Årsskr.* N. F. Avd. 2, 26(6): 1–104, 56 figs.

LEVRING, T. 1941. Die Meeresalgen der Juan Fernandez-Inseln. In, C. Skottsberg, *The natural history of Juan Fernandez and Easter Island*. Vol. 2, 211 pp., Almgrist & Wiksells, Uppsala.

PAPENFUSS, G. F. 1946. Structure and reproduction of *Trichogloea Requienii*, with a comparison of the genera of Helminthocladiaceae. *Torrey Bot. Club, Bul.* 73: 419–437, 26 figs.

YAMADA, Y. 1938. The species of *Liagora* from Japan. *Hokkaido Imp. Univ., Fac. Sci., Inst. Algol. Res., Sci. Papers* 2(1): 1–34, 22 figs., 15 pls.

Notes on Ecology, Systematics, and Development of Some Mysidacea and Euphausiacea (Crustacea) from New Zealand

BRIAN M. BARY[1]

DURING SURVEYING OPERATIONS of H.M.N.Z.S. "Lachlan" in January, February, and March, 1951, opportunities occurred for making biological and oceanographic collections. Stations were kept in eastern and southern nearshore and oceanic waters between Wellington, New Zealand, and Auckland and Campbell islands, some 400 and more miles south of South Island, New Zealand. A series of specimens was obtained which has furnished information on ecology, development, and morphology of a number of southern cool-water species. This report concerns the Crustacea of the orders Mysidacea and Euphausiacea.

Little information, other than of a systematic nature with brief ecological information, has been available on New Zealand zooplankton. In 1923 Tattersall reported on 12 species of Mysidacea from collections made by H.M.S. "Terra Nova" about New Zealand. Seven of these were new species, 6 from the genus *Tenagomysis*. He listed and discussed a total of 15 species, predominantly from the northern, subtropical waters; Chilton (1926) briefly summarised these data. *Tenagomysis*, with 9 species, was regarded by Tattersall as an endemic and characteristic genus of New Zealand, but since then Ii (1937) and Nouvel (1942) have recorded single species from Japan and the Golfe de Gascogne, respectively. Tattersall (1955) adds a further two species, *Boreomysis rostrata* Illig, and *Euchaetomera zurstrasseni* (Illig).

Mysids were absent from the majority of the 86 stations kept from "Lachlan." Two species of *Tenagomysis* were captured, both in the shallow waters (approximately 20 m.) of Foveaux Strait, at the southern extremity of South Island. *T. macropsis* Tattersall was present at 18 and *T. tenuipes* Tattersall at 13 stations. Specimens were abundant at times, and from them it has been possible to provide additional information on the systematic morphology of *T. tenuipes* (described originally from a single male) and to give an account of the larval development of both species.

Tattersall (1924) tabulated 15 species of euphausiids according to their distribution about New Zealand. Eight had been taken by H.M.S. "Challenger" (Sars, 1885) and 7 others were among the 12 species collected by "Terra Nova," all from northern waters. The species belonged predominantly in tropical and subtropical waters.

Five species were present in "Lachlan" collections, namely *Nyctiphanes australis* Sars, *Euphausia lucens* Hansen, *E. vallentini* Stebbing, *Thysanoessa gregaria* Sars, and *Nematoscelis megalops* (?) Sars. *N. megalops* (?) is a new record for the southern Pacific (Boden, 1954), but the others have been recorded previously from New Zealand. The northernmost record of *E. vallentini* was 47° 37′S (171° 47′E) which is in keeping with its more southern range (John, 1936). *E. lucens*, a northern subantarctic species (John, 1936) did not occur south of New Zealand. *Thysanoessa gregaria* occurred sparingly in Cook Strait—between North and South islands—but was present in greater numbers in offshore, subantarctic waters, and it extended southward to Auckland and Campbell islands. *Nyctiphanes australis* occurred only in coastal water.

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Euphausiid developmental stages were captured and these have furnished the larval history of *Euphausia lucens*, a variety of instars of the three furcilias of *Nyctiphanes australis*, and notes on the early furcilia stages of *Thysanoessa gregaria*.

Salinities and temperatures of the waters in which species occurred have been used to confirm the distribution shown by conventional chart plots. Some data on diurnal variation, as indicated through changes with time in numbers taken at the surface, contribute additional information for both mysids and euphausiids.

MATERIAL AND METHODS

Collections were made at 86 stations kept during the surveying routine of the naval frigate, H.M.N.Z.S. "Lachlan." Two series were run between Cook Strait and Dunedin, one in January and the other in March, 1951. The March, but not the January series, crossed the subtropical convergence. The bulk of the stations were situated between Dunedin and

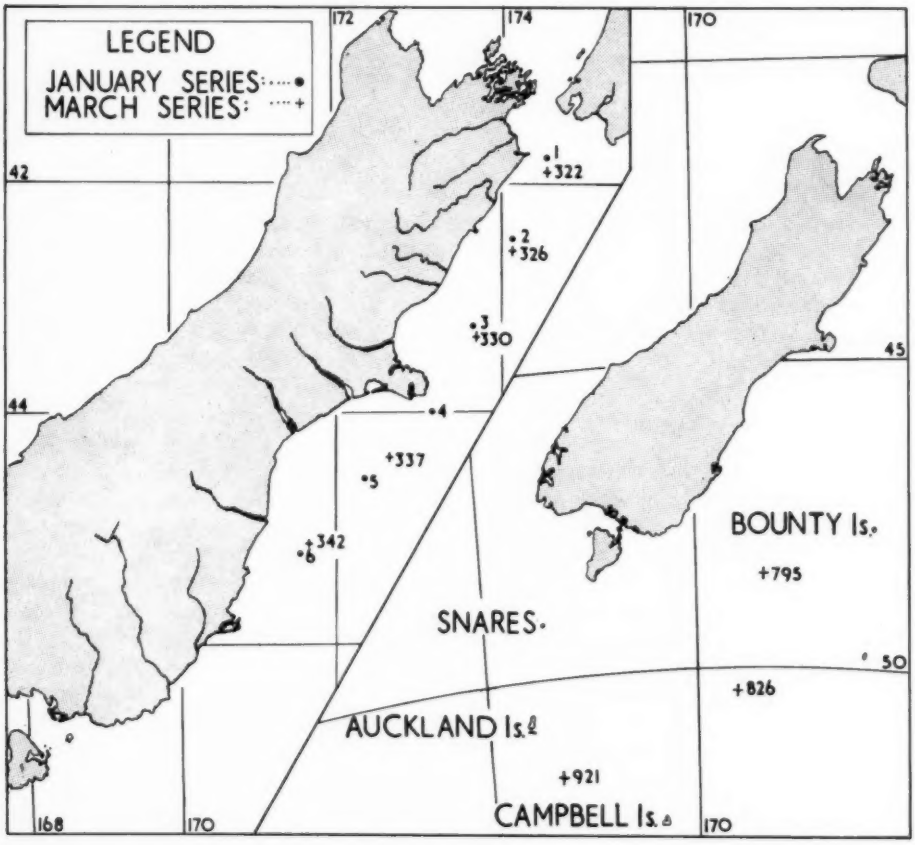


FIG. 1. The plankton stations kept by H.M.N.Z.S. "Lachlan" during January, March, and November, 1951. Left—the January (1–6) and March stations between Cook Strait and Dunedin. Right—the November stations between southern New Zealand and the Auckland-Campbell islands area.

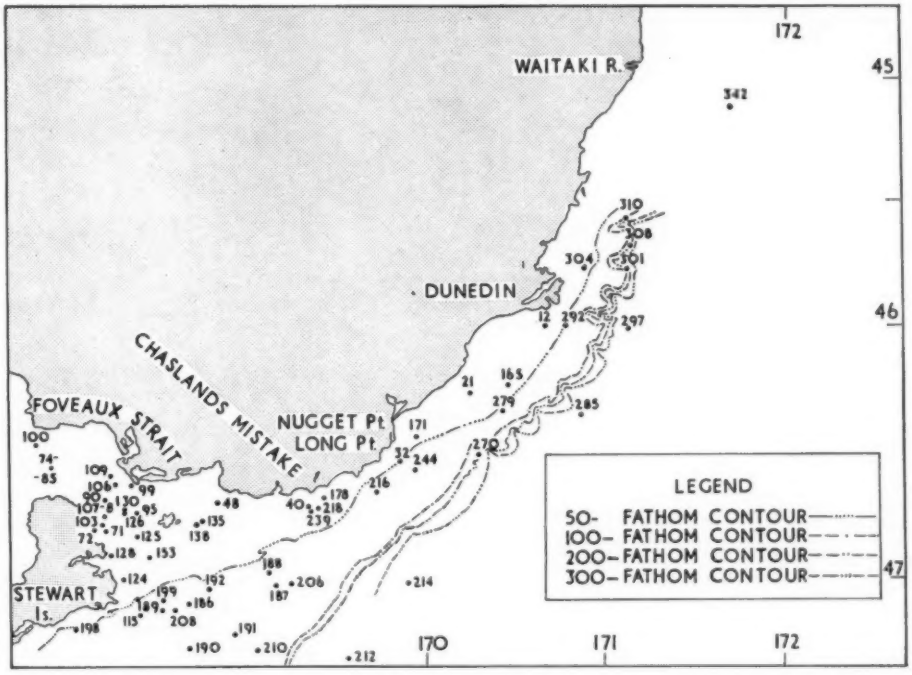


FIG. 2. The plankton stations kept by H.M.N.Z.S. "Lachlan" in and about Foveaux Strait at the southern end of New Zealand during January, February, and March, 1951.

western Foveaux Strait and were kept during January, February, and March 1951. Three were included from a series run between southern New Zealand and the Auckland-Campbell islands area in November 1951. Plankton stations are shown in Figures 1 and 2.

Day and night stations were kept as opportunity permitted. Because the ship's surveying routine could not be interrupted for lengthy tows these were restricted to 3 minutes except at stations 74 to 85 where the net was streamed for 15 minutes (see later). Most were surface hauls, supplemented on occasion with oblique tows from 75 metres to the surface when in deep waters, e.g., on passage from Wellington to Dunedin. As the ship was usually in a particular area for some time, the inadequacy of the 3-minute tow in a position under certain conditions was largely overcome by making numbers of tows under various conditions of time and weather. The net was 50 centimeters diameter with a 16- to 18-mesh grit gauze in the outer portion, a 29-mesh middle portion and 80-mesh inner portion running to the cup. Care was taken to ensure uniform procedure during sampling: the ship's speed was maintained as nearly as possible at 2 knots, and depth of tows made within the surface 2 metres; the same net structure was used throughout the series, the materials being renewed frequently. Because of this standardisation, samples could be compared and some quantitative data obtained.

Surface temperatures and water samples were taken at each net-station, and usually at several intervening positions as well. Salinity determinations were made at the Dominion Laboratory, Wellington.

OBSERVATIONS ON THE SYSTEMATICS AND ECOLOGY OF MYSIDS

Order MYSIDACEA

Suborder MYSIDA

Tribe LEPTOMYSINI

Genus TENAGOMYSIS G. M. Thomson, 1900

Tenagomysis macropsis Tattersall
Figs. 3, 4

Tenagomysis macropsis Tattersall, 1923.

Males, females, and juveniles (one tow consisting of about 60,000 individuals) were taken in 18 samples which were confined to northern and western Foveaux Strait, southern New Zealand.

Tattersall gives a full diagnosis of this species to which reference should be made for greater detail.

Figure 3 illustrates the external appearance of an adult 8.9 mm. male and the fourth pleopod. Characteristics which aid identification are: the rounded rostral plate with anterolateral, curved spines; the elongate eyestalk; the 3 tarsal joints of the thoracic limbs; the spination and proportional lengths of telson and inner and outer uropods, Figure 4*b*.

Tenagomysis tenuipes Tattersall
Fig. 5

Tenagomysis tenuipes Tattersall, 1918, 1923.

Tattersall described this species from a single male, 21 mm. long, taken in Carnley Harbour, Auckland Islands. In the present samples almost 500 specimens of both males and females were taken in 13 hauls from western Foveaux Strait (in the same area as, and often together with, *T. macropsis*) and from eastward of Stewart Island. Numerous juveniles were also captured.

Mature males reached a length of 21.3 mm. and mature females 19.9 mm. Brood-pouch juveniles, ready to be shed, were 4.2 mm. in length. Tattersall's diagnosis is adequate, but

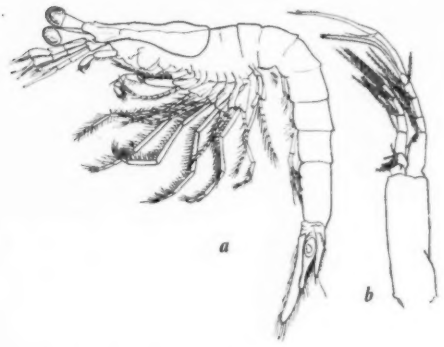


FIG. 3. *Tenagomysis macropsis* Tattersall. *a*, An 8.9 mm. adult male; *b*, fourth pleopod.

inasmuch as large numbers of both sexes were examined in the present material, and some additional information obtained, a full description is given.

Both males and females are moderately slender with large black eyes; they are often brown (preserved) with conspicuous chromatophores.

The carapace exposes the last two thoracic segments completely; it is approximately one-third the length of the body, is produced anteriorly into a broadly triangular rostral plate and has rounded anteroventral angles (Fig. 5*a*).

The peduncle of antenna 1 (Fig. 5*a*, *b*) is long and slender in the female, but stouter in the male with a long, densely hirsute male process. Segment 1 is slender, curves outward and dorsad, and is longer than segments 2 and 3 together; segment 2 is approximately one-third as long as segment 3 which has, distally, a stout mediodorsal spine and three or four lateral setae.

In antenna 2, the peduncle of the endopod (Fig. 5*a*, *c*) is not as long as segment 1 of antenna 1. There is a stout spine ventrally on segment 1 of the endopod, and segment 2 is longer than segments 1 or 3. The squame is 11 or 12 times as long as wide and extends from one-sixth to one-fourth of its length beyond the peduncle of antenna 1. It pos-

sesses an articulation distally at 0.9 of its length and a stout spine ventrally on its basal segment; a bluntly pointed process extends dorsad between the basal segments of the squame and endopod.

The thoracic appendages are long and slender. Each limb has a multi-jointed tarsus, the number of joints being 5 on the first two legs, 8 or 9 on the third, 11 to 14 on the fourth to the seventh, and 9 or 10 on the eighth. There is some indication that females may have one or two fewer joints on some legs (see Table 1). Epipodial processes are pronounced, especially on the first leg (Fig.

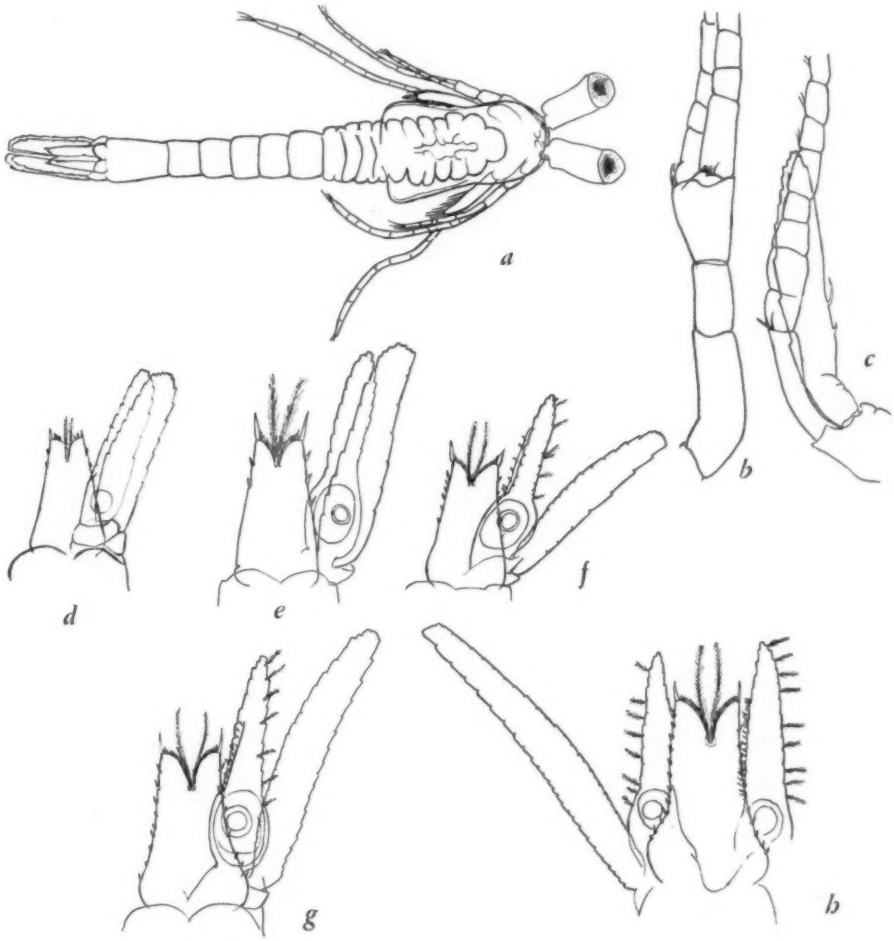


FIG. 4. *Tenagomysis macropsis*. *a–g*, Developmental stages: *a*, A 2.2 mm. specimen from the brood pouch, (thoracic limbs not shown); *b*, antenna 1 of same; *c*, antenna 2 of same, with squame developing; *d*, telson and uropods of same; *e*, telson and uropods of a 2.7 mm. (free living) specimen; *f*, telson and uropods of a 5.0 mm. specimen; *g*, telson and uropods of a 7.0 mm. specimen. *h*, Telson and uropods of adult, 9 mm. male. Magnification of *f* and *g* is 0.6 that of *d* and *e*.

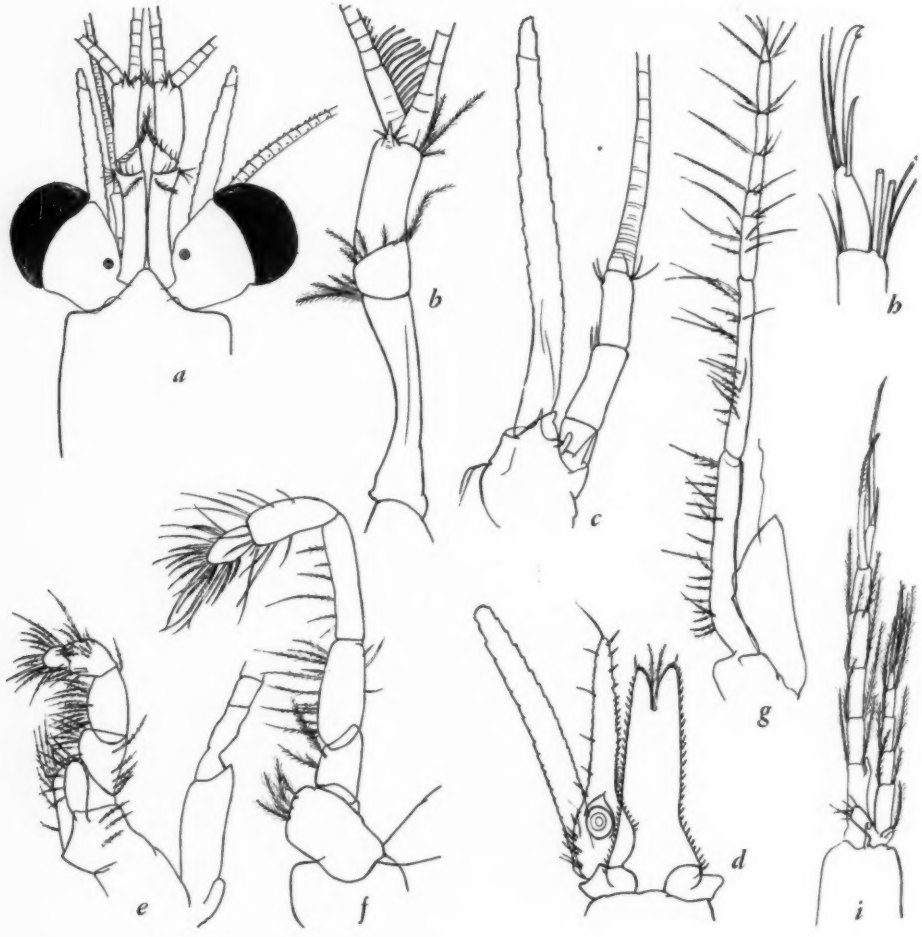


FIG. 5. *Tenagomysis tenuipes* Tattersall. *a–h*, Structure of a 9.8 mm. specimen. *a*, Anterodorsal aspect; *b*, antenna 1, dorsal; *c*, antenna 2, with squame; *d*, telson and uropods; *e*, first thoracic limb; *f*, second thoracic limb; *g*, third thoracic limb; *h*, dactyl of thoracic limb. *i*, The fourth pleopod of a 16.9 mm. male.

5*e*, *f*), and setose, the number of setae decreasing from leg one to leg eight which has a few only. Exopods are present on all legs; the basal segment is freely acuminate at the outer distal corner and the flagella has 9 segments on all except the first leg on which it has 8.

There are no spines on the abdomen and the sixth somite is twice as long as the fifth and as long as the telson.

The telson (Fig. 5*d* illustrates the telson and uropods of a half-grown specimen) is ventrally keeled and is cleft for one-fifth of its length; the cleft has 50 to 60 pectinations

to each margin and 2 plumose setae at its apex; the lateral margins are provided with about 36 spines and one, longer terminal one. The inner uropod is 1.25 times as long as the telson and carries 85 to 90 spines on its inner margin, often in groups of 2 to 4; for most of the length of the uropod these spines are closely spaced, but the spacing increases distally. On the outer margin are the usual long setae, and an additional series of short ones which are more densely grouped about the position of the statocyst. The outer uropod is 1.5 times as long as the inner, is narrow and more or less parallel-sided.

In pleopod 4 of the male (Fig. 5*i*) the outer ramus is almost twice the length of the inner; the penultimate and antepenultimate segments bear long spines, each with spinules which, on the penultimate spine, occur over almost its whole length and on the antepenultimate spine, over the distal half only. Proximally and medially on the first segment of the outer ramus is a short blunt process which is inclined towards the abdomen; distally on the same side of the same segment is a much longer process pointing away from the abdomen. The first segment of the inner ramus of pleopod 5 bears the usual proximal inner lamella, and there is an additional, smaller one carrying a single seta, at the distal one-third of the same segment.

Table 1 indicates that a general increase in the number of joints in the tarsal segment and some small variation in the number of joints of any one limb may occur. The latter variations may be apparent in a single specimen, e.g., in leg 7 of the 21.3 mm. male where on one side there are 13 joints and on the other, 14.

Except for secondary sexual characters, the fewer joints which appear to be present in the tarsus, and the more slender peduncle of antenna 1, there are few apparent differences between female and male.

DEVELOPMENT OF JUVENILES OF *Tenagomysis macropsis* AND *T. tenuipes*

The data which follow are additional to Tattersall's and are included in view of the frequency with which catches of juveniles were made and the initial difficulties experienced in their identification. The often large catches indicate that these larval forms make a significant contribution to the plankton of the area and therefore, should be considered in future investigations.

Development appears continuous, there being no clearly definable stages comparable with those of euphausiids. Prior to release from the brood-pouch, in both species, the cephalothorax is relatively larger than the abdomen (due to the presence of more or less yolk from the large egg), the limbs are stouter and less setose, and the proportions of telson and uropods differ from the corresponding adult structures. The changes associated with these during growth are the most noticeable features of development.

Tenagomysis macropsis juveniles of 2.2 mm. in length (Fig. 4*a*) are retained in the brood-

TABLE 1

THE INCREASE IN NUMBER OF TARSAL JOINTS WITH INCREASE IN LENGTH IN *Tenagomysis tenuipes*

LIMB	LENGTH OF SPECIMEN				
	4.2 mm.	8.0 to 9.0 mm.	16.8 mm. (Male)	21.3 mm. (Male)	19.9 mm. (Female)
3	2	5	8	9	8
4	2	6	9	11	10
5	3	6	10	13	11
6	3	7	12	13	12
7	3	7	13	13–14	12
8	2	6	9	10	9

pouch where there may be as many as 25 present. Both antennae 1 and 2 (Fig. 4*a*, *b*) are incompletely developed; the squame of antenna 2 (Fig. 4*c*) is not articulated distally and has only 2 or 3 outer lateral setae; the peduncle of the endopod is not clearly segmented. In the peduncle of antenna 1 (Fig. 4*b*), segment 2 is slightly longer in comparison to segments 1 or 3 than it is in the adult. Both uropods (Fig. 4*d*) are setose; the inner is very slightly the shorter, contains the elements of a statocyst, but bears no spines on the inner margin. On the margins of the telson there are 2 or 3 lateral, and 1 terminal, spines; there are 4 to 6 spinules and 2 plumose setae in the cleft. From about 2.5 mm. the young are free in the water and there is a sturdier appearance to the appendages. The cleft of the telson has about 11 spinules (see Fig. 4*e*, for 2.7 mm. specimen) per side and the statocyst of the inner uropod is better differentiated; the outer uropod is slightly longer relative to the inner one. In 5.0 mm. specimens (Fig. 4*f*) the outer uropod is noticeably longer than the inner and the latter has developed a series of 6 to 7 spines near the inner margin and several extra setae on the outer; the statocyst is well developed. There is an increase of lateral spines on the telson to 5 or 6 and spinules in the cleft to about 17. In specimens 7.0 mm. long (Fig. 4*g*) the outer uropod is markedly longer than the inner and on the inside margin of the latter the number of spines has increased to 11. The telson now has 7 to 9 lateral spines and 20 or more spinules in the cleft and is developing a waisted appearance as the basal one-third or so is becoming more bulbous in outline. Between a length of 7.0 mm. and the adult size of 8 to 9 mm. (Fig. 4*h*) there is a further increase in the number of lateral spines on the telson to 11 or 12, of the cleft spinules to 27 to 30, and of the spines on the inner margin of the inner uropod to about 22.

In addition to these specific changes, there is a progressive lengthening of the limbs and increased definition of cephalic, thoracic, and abdominal regions as adulthood is approached.

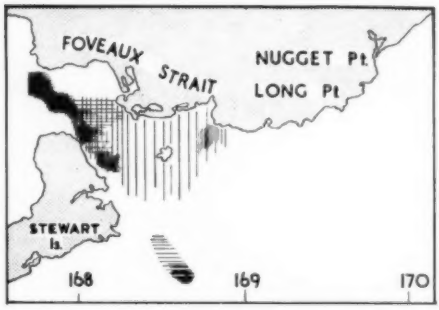


FIG. 6. The distribution of *Tenagomysis macropsis* (vertical lines) and *T. tenuipes* (horizontal lines) about southern New Zealand. Abundance is indicated by the density of the shading.

In *T. tenuipes* the differences between juvenile and adult are similar in kind to those of *T. macropsis*. In contrast to *T. macropsis* the number of joints in the tarsus of thoracic appendages increases with the age of specimens (Table 1).

Individuals of 8 to 9 mm. (Fig. 5*a–g*) illustrate the differences to be expected. The telson (Fig. 5*d*) has 29 to 30 lateral spines, which may be roughly in groups of longer and shorter spines, with the distal ones the more closely spaced and shorter. The cleft has approximately 29 pectinations. The outer uropod is 1.2 times the length of the inner and 1.3 times as long as the telson; the inner uropod has 32 to 35 spines on the inner margin and these tend to be in groups of 3 proximally and to be longer and more widely spaced distally; the outer margin bears secondary setae which are more numerous about the statocyst.

Thoracic limbs 1 and 2 (Fig. 5*e*, *f*) are essentially as in the adult. Limbs 3 (Fig. 5*g*) to 8 are long and slender with reduced numbers of joints in the tarsus. Table 1 indicates the progressive increase in the number of joints in these limbs in specimens ranging in length from 4.2 mm. (about to be shed from the brood pouch) to an adult male of 21.3 mm.

In other features there are slight changes in the proportions of one part with another, e.g., the eyes of smaller specimens are proportionally larger, and the limbs are stouter, but such are usually not of sufficient degree to cause confusion of identity.

The known distribution of both *T. macropsis* and *T. tenuipes* has been extended by the present collections. *T. macropsis* had previously been recorded from northern New Zealand, eastwards almost to Chatham Islands ("Terra Nova," sta. 242), to Dunedin. The present records from Foveaux Strait (Fig. 6) increase the range southward and westward and appear to be consistent with the previous ones.

The range of *T. tenuipes* has been brought 200 miles northward from the Auckland Islands to southern New Zealand, which also involves an increase in temperature of at least 6°C. Both records are from shallow, inshore waters; the species has not been collected between the two areas and may be regarded as a neritic one.

DIURNAL VARIATION OF NUMBERS AT THE SURFACE

Tattersall (1936 *b*), in a short account of vertical distribution, showed diurnal migration occurring for two species of mysids taken by the Great Barrier Reef Expedition. This appears to be the only account of vertical distribution or diurnal movements of mysids for waters of the Southern Hemisphere. Dakin and Colefax (1940: 129) state that a rise to the surface is usual at night, and that probably they collected specimens at no other time. Hardy and Günther (1935) record neither vertical distribution nor migration for the species at South Georgia. There are no previous data for New Zealand mysids.

The data presented below are derived from surface tows and are indicative of vertical migration only through the variation, with time, of numbers at the surface. Further, they are from collections (sta. 74 to 85) made in western Foveaux Strait with the ship at anchor in a tideway wherein the net was streamed for

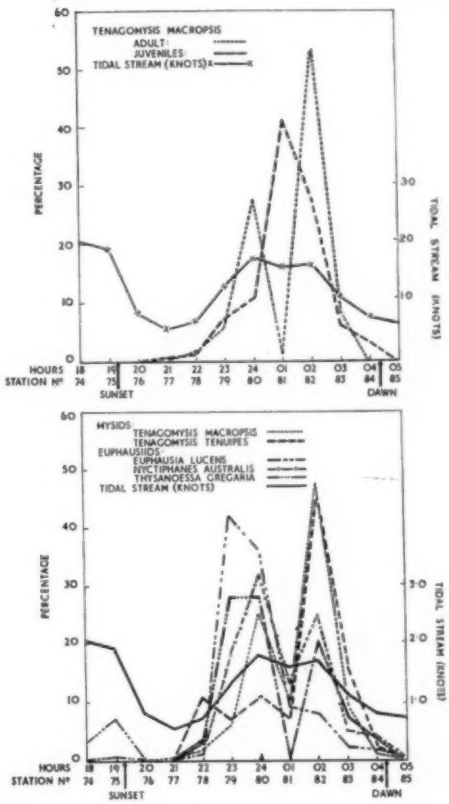


FIG. 7. The variation in numbers of mysids and euphausiids captured in surface tows in a tideway—station series 74–85, western Foveaux Strait. The catch of each species at a station is expressed as a percentage of its total catch for the series. *Upper*, differential movements of adult and juvenile *Tenagomysis macropsis*. *Lower*, diurnal variation of mysids and euphausiids.

15 minutes each hour. In this method of working, the velocity of water passing through the net may vary considerably from tow to tow, but in this instance, it was almost constant at from 1.7 to 2 knots between 2400 and 0200 hours (see Fig. 7 in which the rate of flow, computed from hourly observations made from the ship, is plotted) and under half a knot less an hour previous, or subsequent, to these times. Size of catch prob-

ably did vary over the period required to complete the station series because of the velocity changes in the tidal flow, but nevertheless, the variations in numbers taken conform in general to other diurnal migration patterns (Cushing, 1951); especially is this so between 2300 and 0200 hours.

In Figure 7 the curves express the number of specimens per haul as a percentage of all specimens of that species taken in all the hourly hauls. These curves (except for that of juvenile *T. macropsis*—see below) follow a pattern which is normal (Cushing) in that there is a "main rise" with a subsequent decline in numbers which in turn is followed by a later rise and then the descent from the surface.

Tenagomysis macropsis (Fig. 7, lower) becomes increasingly numerous from 2100 to 2400 hours when there is a sudden decline to 0100 hours; a second peak of high numbers is reached at 0200 hours followed by a rapid decrease to 0300 hours and then an easing to 0400 hours; at 0500 hours, in full daylight, no specimens were captured. *T. tenuipes* occurred irregularly and in small numbers until 0100 hours. There was no significant increase at midnight (compare with *T. macropsis*), but following a slight decrease in numbers at 0100 hours, which repeats a similar decrease at 2300 hours, there is a sudden increase, coincident with that for *T. macropsis*, to a peak at 0200 hours. The subsequent decline in numbers parallels that of *T. macropsis*.

The great increase in numbers of both species of mysids at 0200 hours coincides with a similar, but not as great, increase in two species of euphausiids, (see later and Fig. 7). As there still remain 2 hours to dawn—first light at 0410 hours—this increase would not appear to be associated with the usual predawn rise, which with Copepoda was indicated by an increased catch at 0300 hours. As this behaviour accorded in the 2 mysid and 2 euphausiid species and as their subsequent reactions were similar, it would appear that for these species, under the conditions experienced, the rise at 0200 hours was a true expression of their behaviour pattern.

A possibility not to be ruled out in the circumstances is that shoals of the relevant species were being sampled, especially at the 0200 tow, in which case, the appearance of a later, small, predawn rise might be masked by the large catches made earlier. That such shoaling is a not altogether reasonable possibility is demonstrated by the independent migrations to the surface of juvenile and adult *T. macropsis*, shown in the upper graph of Figure 7, where the percentage occurrence of juveniles per haul is superimposed on that for adults from the same hauls. Juveniles increase slowly and steadily to 2400 hours when a sudden increase to a single peak at 0100 hours occurs. The subsequent decline indicates a rapid descent from the surface about the time the late rise of adults commences, although both are at the surface in moderate numbers between 0100 and 0200 hours. The juveniles are also somewhat slower at leaving the surface in this series, as is indicated by a catch of 50 as against 3 adults at station 84.

OBSERVATIONS ON THE SYSTEMATICS AND ECOLOGY OF EUPHAUSIIDS

Order EUPHAUSIACEA

Family *EUPHAUSIIDAE*

Genus EUPHAUSIA Dana

Euphausia lucens Hansen

Fig. 8

Euphausia lucens Hansen, 1905, 1911; Tattersall, 1924; John, 1936.

A few of this species were taken from Cook Strait, but the majority were taken around southern New Zealand. None occurred in the subantarctic stations 795, 826, 921 (Fig. 1). In all 3,378 specimens were captured in 37 hauls.

Sub-mature males and females ranged between 10.0 and 11.0 mm. in length; mature specimens reached 16 mm. and exceptionally, 18 mm.

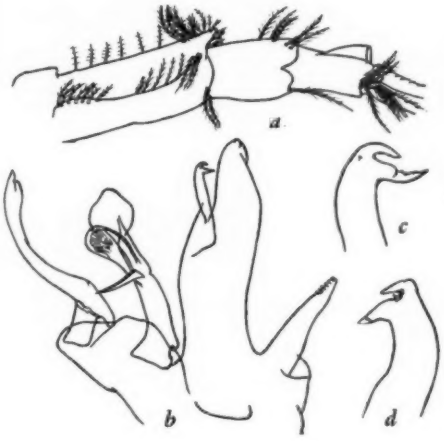


FIG. 8. *Euphausia lucens* Hansen. *a*, Lateral aspect of antenna 1, adult female; *b*, left copulatory organ of 15 mm. male, from behind; *c*, lateral process of left copulatory organ; *d*, lateral process of right copulatory organ.

Features which aid in identification of the species are the broad, triangular lappet (which is variable in size) on the distal inner margin of segment 1, and the shape and size of the keel on the terminal segment, of antenna 1 (Fig. 8*a*); the short, broadly triangular rostrum; absence of dorsal spines on the abdominal segments; and in the male, the detailed structure (Fig. 8*b–d*) of the copulatory organ (John, 1936).

There is a slight discrepancy between John's figures and the present material in the structure of the lateral processes of the copulatory organ (Fig. 8*c*, *d*). In the present specimens one or more minute, subsidiary spines are in association with the terminal tooth of the process. On the lateral process of the left organ there is, as well, a series of denticulations on the outer surface of the curved end (Fig. 8*c*). Probably these are little more than minor differences as the organs are otherwise identical.

According to Tattersall (1924) *E. lucens* is "a species, the centre of whose distribution lies in the south temperate zone, but which occasionally penetrates to the subantarctic region." John regards it as primarily a subantarctic species, not found south of the antarctic convergence, and limited by the subtropical convergence in its northward extent. Both authors regard the 12° to 14°C. isotherms as delimiting its northward extension. The difference in terminology lies in Tattersall's acceptance of Regan's (1914) definition of the southern zones wherein northward of the 12°C. isotherm is south temperate, and south of it, subantarctic zones. John regards the waters between the subtropical and antarctic convergences as subantarctic, the temperature of which ranges from 14.5°C. in the north to 4.5°C. in the south over summer months (Deacon, 1937).

In the present collections *E. lucens* extends to stations 322 and 326, north of the subtropical convergence (Figs. 1, 9); at 322 it occurred only in an oblique haul, and at station 326, 10 specimens were taken in the oblique and 6 in the surface tow. At station 330, just south of the convergence, 13 specimens were present in the oblique, and 21 in the surface, hauls. It is a possibility that the oblique tows at 322 and 326 are sampling from concentrations in colder water (11°C.) which was shown by bathythermograph to be present at 40 to 60 metres, and which was a northward extension of subantarctic, overlaid by subtropical, water. The higher numbers in both hauls at 330 appear to support this. Movement northward beyond the convergence in such colder deeper water may in part explain John's statement that specimens occur in the coldest of the subtropical water along the northern edge of the convergence. Contrarily, this species has been taken in water to about 20°C. (John, 1936: 208); with the temperature tolerance which this indicates specimens could penetrate into the overlying warmer water north of the convergence.

Judging from the present collections *E. lucens* appears to be confined to more northerly subantarctic waters (see Fig. 9) than was found by the "Terra Nova" (Tattersall, 1924)

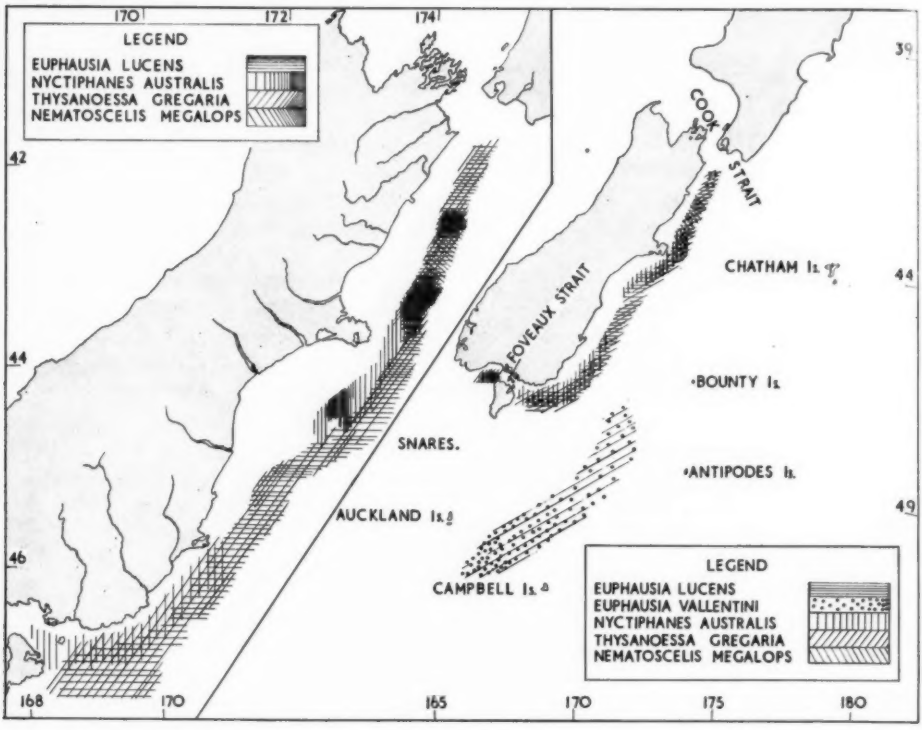


FIG. 9. The distribution of euphausiids between Cook Strait and the Auckland–Campbell Islands area. *Left*, occurrences between Cook and Foveaux Straits. *Right*, occurrences in the sub-antarctic waters in relation to those on the coast of South Island.

or "Discovery II" (John, 1936). No specimens were collected at stations 795, 826 or 921 between southern New Zealand and Auckland Islands—it was replaced by *E. vallentini* (Fig. 9) in these hauls. John (*loc. cit.*) reports, however, that the southern limit of occurrence of *E. lucens* overlaps the northern limit of *E. vallentini;* further sampling is required to show where this occurs to the south of New Zealand.

The pattern of the distribution of *E. lucens* in southern New Zealand waters (Fig. 10) suggests that specimens are entering coastal areas in intruding tongues of subantarctic water. Preponderant occurrence is in a narrow range of salinity between 34.25 and 34.45 parts per thousand which is within that of subantarctic water (34.2 to 34.5 parts per thousand, see Deacon, 1937). Occurrences in water of lower salinities possibly result from intrusions of subantarctic water carrying specimens into dilute coastal water. Some occurrences in waters of higher salinities may be in mixtures with subtropical waters, possibly intruding eastwards through Foveaux Strait.

Euphausia vallentini Stebbing
Fig. 11

Euphausia vallentini Stebbing, 1900; Holt and Tattersall, 1906. Hansen, 1911; Tattersall, 1924; John, 1936.
Euphausia splendens (part), Sars, 1885.

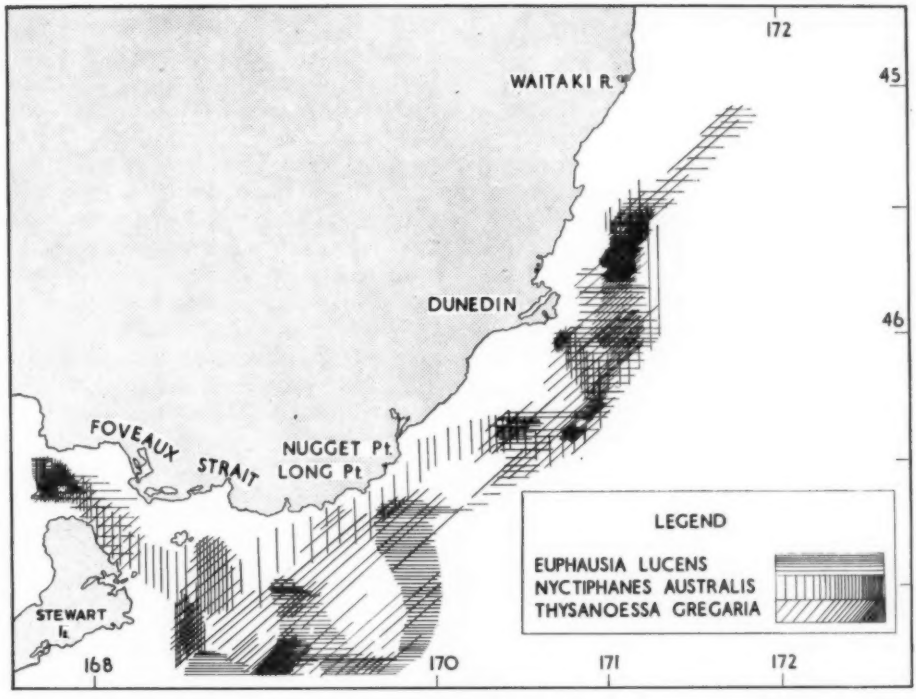


FIG. 10. The distribution of euphausiids, south-eastern New Zealand, for the period January through March, 1951. Abundance is indicated by the density of the shading.

During November 1951, single specimens were taken at each of stations 795 and 826 (at 1900 and 0300 hours respectively) and 24 specimens, including larval stages, at 921 (at 0300 hours). These occurrences (Fig. 9) are in subantarctic waters.

The length of the largest specimen, a female, was 20.5 mm. John (1936) fully describes this species, including larval stages. It is readily identifiable, and also distinguishable from *E. lucens*, by the large, broad, oval lappet distally on segment 1 and the high-arched keel dorsally on segment 3 of antenna 1 (Fig. 11*a–c*), combined with the presence of the "spine" posteriorly in the mid-dorsal line of abdominal segment 3 and the short, acutely pointed rostrum.

E. vallentini is typically associated with subantarctic waters (John). Off New Zealand, specimens have been taken north of the 12°C. isotherm (Tattersall, 1924) and to about 45°S latitude (John, 1936: 213); both of these occurrences were south of the subtropical convergence, northward of which it has not been recorded. In the present collections, the temperature ranged between 9°C. at 47°37′S, station 795, to 8.2°C. at station 921; since the stations were all kept after nightfall, the 24 specimens collected at 921 would suggest that the species is more common in the colder waters of the higher latitudes in November (see Fig. 9). No specimens have been taken in neritic or near-oceanic waters about southern New Zealand, but it is possible that occasionally it might occur in intrusions of subantarctic water in winter months when the temperature of these waters is appreciably lower.

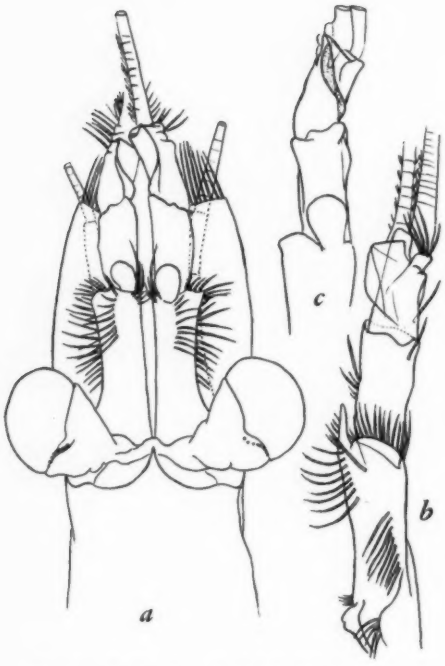


FIG. 11. *Euphausia vallentini* Stebbing. *a*, Anterodorsal aspect, 20.5 mm. female; *b*, antenna 1, lateral aspect; *c*, antenna 1, dorsal aspect.

Genus NYCTIPHANES G. O. Sars

Nyctiphanes australis G. O. Sars

Nyctiphanes australis G. O. Sars, 1883, 1885; G. M. Thomson, 1900; Hansen, 1911; Dakin and Colefax, 1940.

A commonly occurring euphausiid, especially in coastal waters; a total of 3,132 specimens were taken at 28 stations.

Mature females ranged in length from 9.8 to 17.0 mm. and males from 12.0 to 16.0 mm.; thus specimens may mature over a considerable range of size. A very full diagnosis has been given by Sars, 1885; Dakin and Colefax, 1940, illustrate an adult female, a calyptopis, and a furcilia stage.

This species is confined to southeast Australian and New Zealand waters (Hansen, 1911; Tattersall, 1924; Sheard, 1953) and is regarded as a coastal one. It was collected by "Terra Nova" only in the area about, and south of, Three Kings Islands, just north of New Zealand, but Thomson (1913) recorded it as being extremely common in Otago Harbour, where it was important as a fish food.

The distribution from the present collections is shown to be fairly consistently further inshore than the other euphausiids taken (Figs. 9, 10), although overlap along the margins of the species ranges (especially with that of *E. lucens*) is apparent. Comparatively wide salinity tolerance is demonstrated (34.05 to 34.72 parts per thousand), and preference is shown for temperatures, for the most part, above 13.5°C. These data lend support to Tattersall's claim that *N. australis* is a coastal species. The species was absent in tows north of the subtropical convergence, but the earlier records suggest that it may be common throughout our coastal waters.

Genus THYSANOESSA Brandt

Thysanoessa gregaria G. O. Sars
Fig. 12

Thysanoessa gregaria G. O. Sars, 1883, 1885; Hansen, 1911, 1913; Dakin and Colefax, 1940; Einarsson, 1945; Boden, 1954.

A total of 1,256 specimens were taken, mostly in small numbers, at 42 stations; large catches were made only in a night series between Dunedin and Nugget Point (stations 285 to 308; Figs. 1, 9, 10).

The longest specimen was a 16.2 mm. female, but the majority of adults, which were comparatively rare, were between 10 and 13 mm. long; most specimens captured were either furcilia or cyrtopid stages.

The adult possesses a characteristic denticulate plate, the pre-anal spine (Sars, 1885), which, together with the stout form of the body, very long second leg (Fig. 12*b*), large eye, and in the male, the copulatory organ (Fig. 12*a*), contributes to ready identification of the species.

Sars reported *Th. gregaria* from "Challenger" collections made between Sydney and Wellington, Chilton (1911) found it in stomachs of fish from the Kermadec Islands, and Tattersall recorded it in "Terra Nova" catches from south of Three Kings Islands. The latter collections, some 250 specimens from 20 stations, comprised the largest catches until those of the present series. The species is regarded as typically from northern or southern temperate waters (Hansen, 1911; Tattersall, 1924; Einarsson, 1945; Boden, 1954). Although in the southern hemisphere it has several times been recorded in subantarctic waters, i.e., south of the 6°C. isotherm in Regan's (1914) terminology (see Hansen 1913, and Tattersall, 1918) Boden, following an extensive survey, regarded it as a "true temperate or subtropical form" and states that its occurrences in African subantarctic water were "probably transitory."

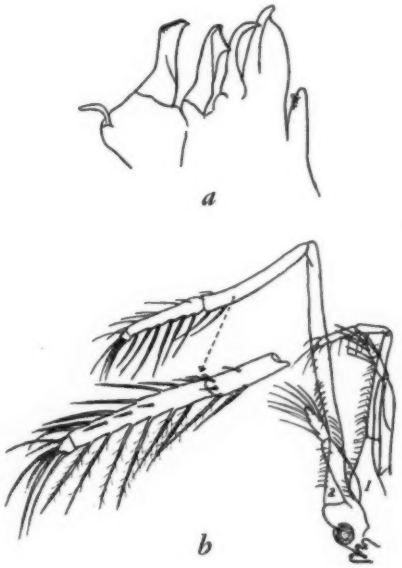


FIG. 12. *Thysanoessa gregaria* G. O. Sars. *a*, Left copulatory organ of adult male, from behind; *b*, first and second thoracic limbs.

In the present collections specimens occurred from Cook Strait to latitude 51° 41'S (station 921 where 30 were collected; Figs. 1, 9); at only six stations were more than 50 specimens taken at one time and of these, stations 210, 297, and 308 had 195, 200, and 496 specimens, respectively. Its consistent penetration into coastal water (Fig. 10) in which temperatures of 15°C. and higher were met, and its presence in subantarctic water of as low as 8.2°C. indicate a considerable temperature tolerance. However, largest catches were made in oceanic water with salinity and temperature characteristics of the subantarctic, suggesting that the species may occur there more frequently than previously thought.

Genus NEMATOSCELIS G. O. Sars

Nematoscelis megalops (?) G. O. Sars
Fig. 13

Nematoscelis megalops G. O. Sars, 1883, 1885; Hansen, 1911, 1915; Esterley, 1914*a;* Banner, 1949; Boden, 1954; Boden, Johnson and Brinton, 1955.

A total of eight females was taken, two from the horizontal and five from the oblique tows at station 326, and one from the oblique tow at station 330 (Figs. 1, 9).

According to Hansen (1911), Banner (1949), Boden (1954), and Boden, *et al.* (1955), the only means of separating the Atlantic species *N. megalops* from *N. difficilis* of the northeast Pacific, is on the structure of the male copulatory organ. On the other hand Einarsson (1942), from a study of the spermathecae of the two species, regards them as identical. Most unfortunately, no male was taken here, and because of this the identification is left open; but the evidence presented in Table 2 appears to favour the specimens being identified as *N. megalops*. The notes for *N. difficilis* are derived from Esterley (1914*a*), Banner (1949), and Boden, *et al.* (1955).

Table 2 lists characters which vary between the two species, suggesting that differences may exist other than those found in the male

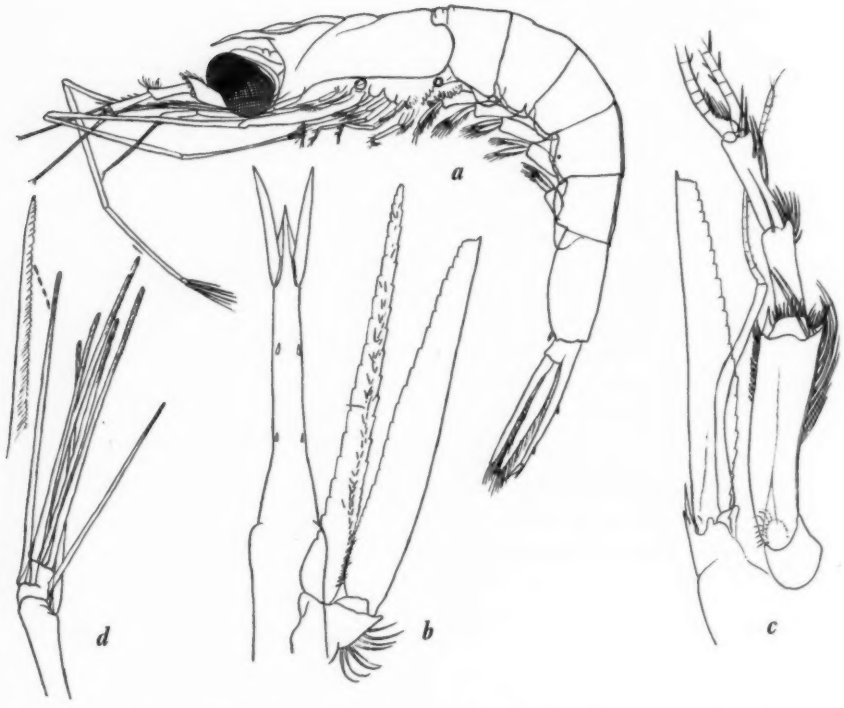


FIG. 13. *Nematoscelis megalops* (?) G. O. Sars; 20.4 mm. female. *a*, Lateral aspect; *b*, telson and uropods; *c*, antennae 1 and 2; *d*, terminal portion of limb 2.

copulatory organs. The median spine-like processes on the fourth and fifth abdominal somites, (or the median keel in the N. Z. specimens?) may prove a convenient distinguishing character in view of their absence (Banner) in *N. difficilis*.

Nematoscelis megalops has been described as one of the characteristic euphausiids of the northwest Atlantic according to Hansen (1911) who mentions that it has also been recorded "at some places in the southern temperate Atlantic," but that females taken in the southern Indian Ocean could not be referred to either *N. megalops* or *N. difficilis*. Boden (1954) reports that *N. megalops* is common about South Africa, but that no records exist of it from the south Pacific. On the other hand, Sheard (1953) records *N. difficilis*, adults and larval stages, as commonly occurring in east Australian waters. He also, doubtfully, records *N. megalops* from the western Indian Ocean.

Specimens of *N. megalops* from the south Atlantic could well get caught up in the West Wind Drift and attain a sparse, subantarctic circum-global distribution, eventually reaching southern New Zealand in the subantarctic water. It is equally possible for *N. difficilis* to be carried into the area from Australia, either in the West Wind Drift, or (and more likely) across the south Tasman Sea via the western drift in that portion of the ocean.

Thus it is possible for either, or both, *N. megalops* and *N. difficilis* to be present in New Zealand waters. Recorded distributions, and more especially proximity to Australia and

direct oceanographic communication from Australia to New Zealand, suggest that the New Zealand specimens may be *N. difficilis*. The morphological features listed in Table 2, however, favour their being *N. megalops* and accordingly the species is provisionally listed as *N. megalops*.

EUPHAUSIID LIFE HISTORIES

There are numerous accounts of larval development of a wide range of species of the Euphausiacea. Einarsson (1945) has treated the historical progress in these studies and has reviewed the terminology of the developmental phases. Gurney (1947) reviews development. Sheard (1953) briefly covers historical features and theories of development; he also discusses "dominance" among larval instars and questions the validity and usefulness of the concept. Boden (1955) discusses in turn Sheard's view towards dominance and also his "lumping" of the numerous furcilias of *N. australis*, and those of other species into three furcilia stages. Boden is of the opinion that dominance is still a useful concept, and that, "under the present circumstances it is less useful to 'lump' the furcilia stages than to 'split' them."

Some life-history stages are available from the "Lachlan" material for *Nyctiphanes australis* and *Thysanoessa gregaria;* the three calyptopis, and a complete series of furcilia stages for *Euphausia lucens*. There is little doubt that in the present material dominant instars occur for the oceanic species *E. lucens* and *T. gregaria*. For the coastal species *N. australis*, a tendency for dominant instars to occur is explained as due to the local nature of the collections (see Sheard, 1953); Sheard's grouping of the instars has been followed for this species.

Development of Euphausia lucens

John (1936) combines *Euphausia crystallorophias*, *E. superba*, *E. frigida*, *E. vallentini*, and *E. lucens* into a group of related species (his "Southern Group"); of these, closest relationship is considered to exist between *E. lucens*, *E. vallentini* and *E. frigida*. He describes the development of *E. vallentini* and *E. frigida* (but not of *E. lucens*) and the close relationship of adults of the two species is reflected in the similarity of their development

TABLE 2

DIAGNOSTIC CHARACTERS OF *Nematoscelis difficilis* AND *N. megalops* (FROM VARIOUS AUTHORS) AND THEIR COMPARISON WITH FEMALE *Nematoscelis* FROM NEW ZEALAND

CHARACTER	*N. difficilis*	*N. megalops*	*N. megalops* (?)
Ratio of lengths of segments 1 to 3 of antenna 1	1 : 0.6 : 0.65	1 : 0.5 : 0.45	1 : 0.47 : 0.45
Squame	Reaches to half length of segment 3 of antenna 1	Reaches to end of segment 3 of antenna 1	Reaches almost to end of segment 3 of antenna 1
Ratio of length of telson to abdominal somite 6	3.8 : 2 (Boden *et al.* 1955, fig. 40a)	3 : 2	3 : 2
Dorsal armature on abdomen	Denticles not present	Small, mediodorsal spine-like processes on 4th and 5th somites	Low, mediodorsal keels on 4th and 5th abdominal somites which terminate in a short spine-like process on the posterior margin of each of the somites

TABLE 3

COMPARISON OF LARVAL CHARACTERS OF *Euphausia frigida*, *E. vallentini*, *E. lucens* AND (?) *E. lucens* FROM SOUTH AFRICA

STAGE	CHARACTER	*E. frigida*	*E. vallentini*	*E. lucens*	(?) *E. lucens*
Calyptopis I–III	Carapace	Smooth, rounded frontal margin; no posterior spine; lateral denticles in Stage III.	Same as *E. frigida*	Same as *E. frigida*	Strongly spinose, very broad, rounded and medially cleft. Large postero-dorsal spine. Lateral denticles present, all stages.
	Length, mm.	I ..... II 1.7–1.8 III 2.5–2.9	..... 1.6–1.8 2.5–2.8	0.9–1.2 1.4–1.7 2.1–2.5	0.98–1.0 1.3–1.8 2.10–2.33
Furcilia I	Frontal plate	Broadly rounded, non-spinose	Angularly rounded, non-spinose	Broadly rounded, non-spinose	Very broad, strongly spinose margin, medially cleft.
	Pleopods	4 non-setose	4 non-setose	4 non-setose	1 non-setose
	Telsal spines	7	7	7	7
	Length, mm.	3.8–4.3	3.2–4.0	2.7–3.2	3.0
II	Pleopods	4 setose, 1 non-setose	4 setose, 1 non-setose	4 setose, 1 non-setose	1 setose, 4 non-setose
	Telsal spines	7	7	7	7
	Length, mm.	4.7–5.7	4.5–5.1	3.4–4.1	3.5
III	Pleopods	5 setose	5 setose	5 setose	5 setose
	Telsal spines	7	7	7	7
	Length, mm.	5.5–6.7	5.4–6.1	4.0–5.0	.....
IV	Pleopods	5 setose	5 setose	5 setose	5 setose
	Telsal spines	5	5	5	5
	Endopod of antenna 2	segmented	segmented	segmented	unsegmented
	Length, mm.	6.5–7.7	5.4–6.1	4.7–5.5	.....
V	Telsal spines	3	3	3	3
	Endopod of antenna 2	.....	.....	.....	segmented
	Length, mm.	7.0–8.3	6.1–7.6	5.0–6.1	.....
VI	Telsal spines	1	1	1	1
	Length, mm.	6.8–9.6	6.2–9.3	5.0–6.0	.....

(see Table 3). It might be expected that *E. lucens* would also exhibit a developmental series similar to those of *E. frigida* and *E. vallentini*, and the New Zealand material proves this to be so.

Boden (1955) has described the calyptopis and the first two furcilia stages (with brief notes on later stages) of what was believed to be *E. lucens*, from a small amount of material collected in the area of the Benguela Current. The developmental series of his material is widely at variance with the species relationship discussed above, and it would appear that the species described may be other than *E. lucens*. The New Zealand material supports such an opinion. It supplies a continual series of stages from calyptopis to adult *E. lucens* which, even though similar to *E. frigida* and *E. vallentini*, is unlikely to be confused with developmental stages of these species inasmuch as *E. frigida* is only exceptionally found north of the antarctic convergence and no adults of *E. vallentini* were captured in the waters where *E. lucens* was abundant. Further, furcilias of *E. lucens* are considerably smaller, especially in later stages, than for the other species, see Table 3.

Relevant information for comparing *E. lucens*, *E. frigida*, *E. vallentini* and Boden's material is summarised in Table 3.

The stages of *Euphausia lucens* obtained, following John's (1936) system of nomenclature, are as follows:

Calyptopis: Stages I, II, and III.
Furcilia:

Stage I. With four pairs of non-setose pleopods.
Stage II. With four pairs of setose, one pair of non-setose pleopods.
Stage III. With five pairs of setose pleopods; 5 terminal spines to telson; endopod of antenna 2 unsegmented.
Stage IV. Telson with 5 terminal spines; endopod of antenna 2 segmented; squame differentiated.
Stage V. Telson with three terminal spines.
Stage VI. Telson with one terminal spine.

FIRST CALYPTOPIS: (Fig. 14*a–e*). Length, 0.9 to 1.2 mm. (average 1.0 mm., 9 specimens measured).

The carapace (Fig. 14*a*) is rounded at frontal and posterior margins, longer by one-third than the abdomen, and without lateral denticles. The peduncle of antenna 1 is not segmented. There are indications of segmentation on the abdomen. The telson is short (Fig. 14*b*) with 7 terminal spines and 4 pairs of lateral spines of which the anterior pair is ventrolateral. The mandible, and maxillae 1 and 2 are illustrated (Fig. 14*c*, *d*, *e*). The first thoracic limb is segmented, and the terminal portion is bifurcate.

SECOND CALYPTOPIS: (Fig. 14*f*, *g*). Length, 1.4 to 1.7 mm. (average 1.6 mm., 15 specimens measured).

The carapace possesses a small dorsal organ and no lateral denticles; it is broadly rounded anteriorly and posteriorly (Fig. 14*f*), slightly constricted behind the eyes, widest in the posterior half and is almost as long as the abdomen. Thoracic segments 2 to 8 are visible as narrow annulations between the first thoracic limb and the abdomen which has five segments. The telson (Fig. 14*g*) is as described for the first calyptopis, but is longer and more slender; there are no uropods. The peduncle of antenna 1 (Fig. 14*f*) has 2 or 3 segments; one of the flagellae is represented by the terminal portion of the ultimate segment of the peduncle, the other by a minute segment. The eyes are rudimentary and covered by the carapace. The maxillae and limb 1 are essentially as in Stage I.

THIRD CALYPTOPIS: (Fig. 14*h*, *i*). Length, 2.1 to 2.5 mm. (average 2.3 mm., 14 specimens measured).

The carapace possesses a dorsal organ and a small posterolateral denticle on each ventral margin; the anterior margin is squarer, the posterior margin more rounded than in the

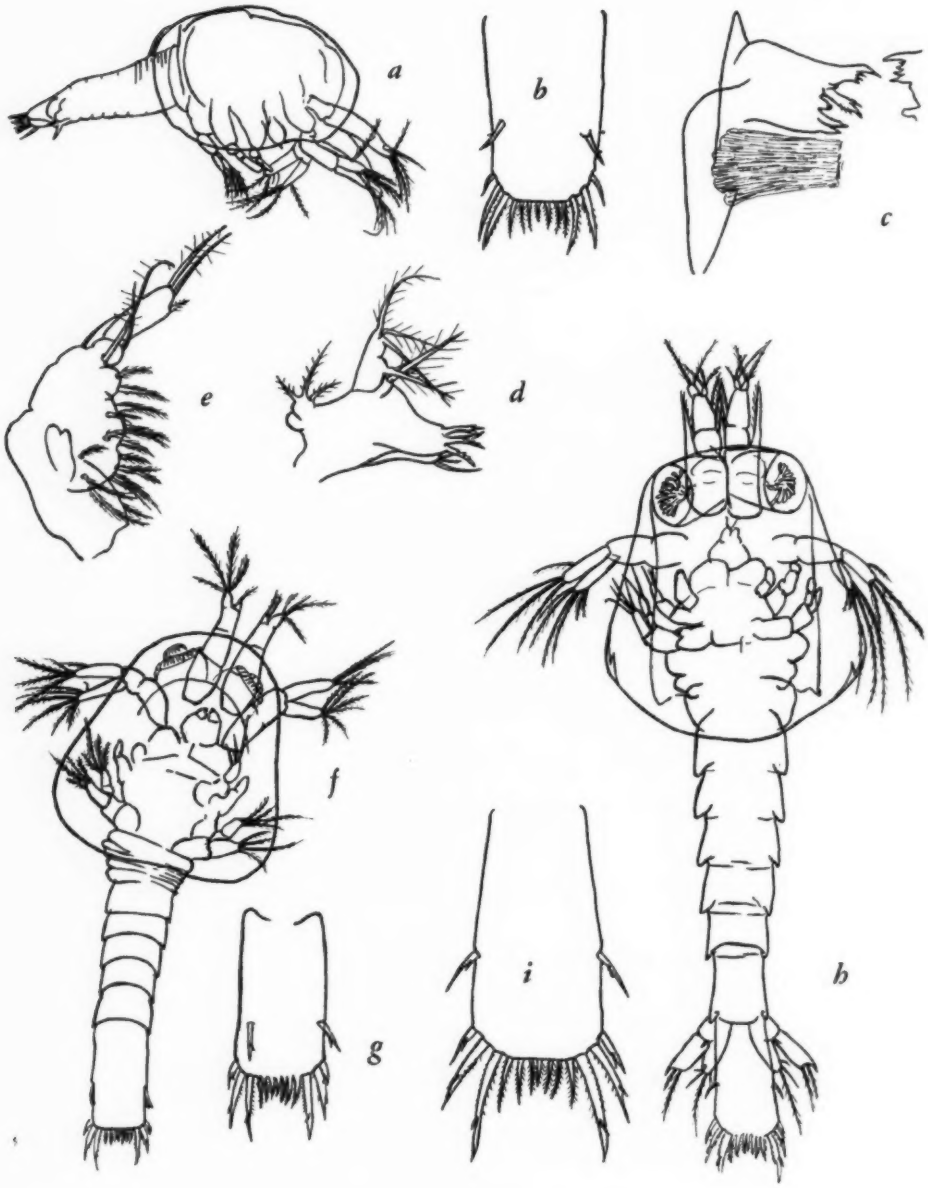


FIG. 14. Calyptopis stages of *Euphausia lucens* Hansen. *a–e*, Stage I: *a*, Lateral aspect of 1.0 mm. specimen; *b*, telson; *c*, mandible; *d*, *e*, first and second maxillae. *f*, *g*, Stage II: *f*, Dorsal aspect of 1.5 mm. specimen; *g*, telson. *h*, *i*, Stage III: *h*, Dorsal aspect of 2.4 mm. specimen; *i*, telson. *a*, *f*, *g*, ×50.

previous stage, but the slight constriction is still present behind the eyes; it is much broadened posteriorly (Fig. 14*h*). On segment 1 of the peduncle of antenna 1 there is a well-developed lateral spine which reaches to the end of segment 3; both flagellae are segmented off from the peduncle. The eyes are well defined and becoming pigmented but are still covered by the carapace. The abdomen has 6 segments and a telson, and is 1.5 times the length of the carapace. There are 7 terminal spines on the telson (Fig. 14*i*) which is flanked by inner and outer uropods. There are rudiments of limbs enclosed in a common sheath posterior to limb 1.

Stages II and III are very similar to the corresponding stages for *E. frigida* and *E. vallentini* (see John, 1936, who does not describe Stage I). That they are not of these species must be assumed from the facts, firstly that no adults of either were taken as far north as southern New Zealand, where these calyptopids were captured, and secondly, that the furcilias with which they are continuous are smaller than those for either *E. frigida* or *E. vallentini*.

FURCILIA, STAGE I: (Fig. 15*a–d*). Length 2.7 to 3.2 mm. (average 3.0 mm., 17 specimens measured).

This stage has 4 pairs of non-setose pleopods and 7 terminal spines on the telson. The carapace (Fig. 15*a*, *b*) possesses a distinct dorsal organ, lateral denticles, and anteros ventral spines; the rostral plate is as wide along, or wider, with the frontal margin slightly rounded. The spine on the outer distal corner of segment 1 of antenna 1 is usually as long as segments 2 and 3 combined, but may reach only halfway along segment 3. The first thoracic limb is bifurcate; the second (Fig. 15*c*) is rudimentary, with elements of exopodite and gill developing; other limbs are buds enclosed in a common sheath (Fig. 15*a*). Uropods reach to, or almost to the first pair of lateral spines (Fig. 15*d*) which are situated at between one-half and two-thirds the length of the telson.

FURCILIA, STAGE II: (Fig. 15*e–g*). Length, 3.4 to 4.1 mm. (average 3.8 mm., 28 specimens measured).

This stage is characterised by 4 pairs of setose and 1 pair of simple pleopods, and 7 terminal spines on the telson. The rostral plate is rounded, or angularly rounded (Fig. 15*e*), is broader at the base than long, and usually has a minute terminal spine. Thoracic limb 2 (Fig. 15*f*) comprises 3 or more segments, is setiform and possesses a rudimentary exopodite and gill; limb 3 is a kneed rudiment and has a rudimentary gill; limbs 4 to 6 exist as buds. The distolateral spine of segment 1 of antenna 1 extends to halfway or more along segment 3. The first abdominal segment has a pronounced tergal wing extending dorsally and laterally (Fig. 15*e*). The telson (Fig. 15*g*) is 4.5 times as long as wide and inner and outer uropods reach to, or a little beyond, the lateral spines.

FURCILIA, STAGE III: Length, 4.0 to 5.0 mm. (average 4.7 mm., 16 specimens measured).

There are 5 setose pleopods and 5 terminal spines (6 in two specimens) on the telson. The rostral plate is similar to that of the previous stage. The endopod of antenna 2 is unsegmented. The distal spine of segment 1 of antenna 1 extends for half, or less, of the length of segment 3; the flagellae are elongating. The endopod (inner ramus) of thoracic limb 1 is elongating; limb 2 is setiform and possesses 3 tarsal joints (sub-segments); limb 3 may have 3 joints or be indistinctly segmented in the tarsus; limb 4 is kneed, 2-segmented and with elements of gill and exopodite; limbs 5 and 6 are rudiments. The outer uropod is as long as the inner which reaches from one-third to halfway between the lateral and the first (outer) post-lateral spines; the inner has 3 or 4 setae on its outer margin. The inner pair of post-lateral spines are broadening basally.

FURCILIA, STAGE IV: (Fig. 15*h–j*). Length, 4.7 to 5.5 mm. (average, 5.2 mm., 6 specimens measured).

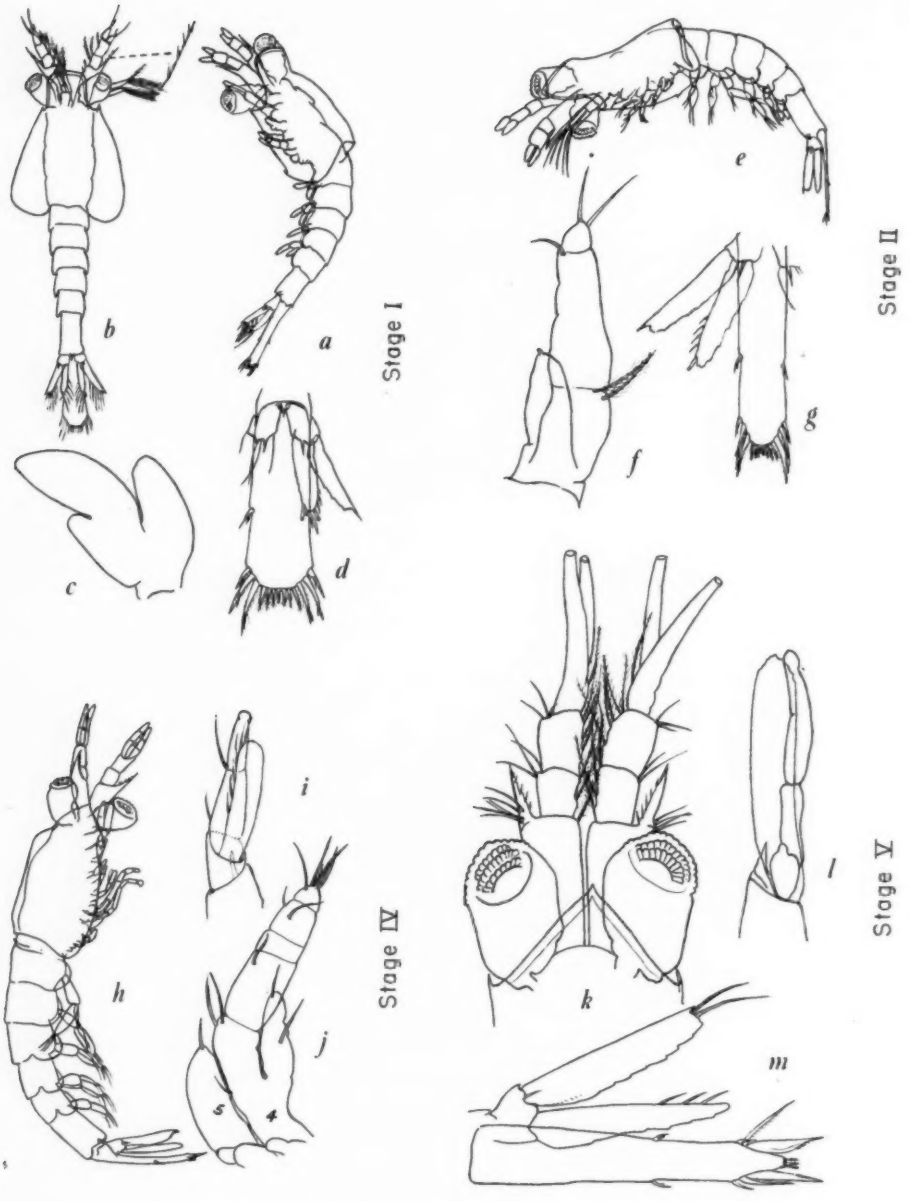


FIG. 15. Furcilia stages of *Euphausia lucens* Hansen. *a–d*, Stage I: *a*, Dorsolateral aspect of 3.2 mm. specimen; *b*, dorsal surface; *c*, second thoracic limb; *d*, telson and uropods. *e–g*, Stage II: *e*, Dorsolateral aspect of 4.0 mm. specimen; *f*, second thoracic limb; *g*, telson and uropods. *h–j*, Stage IV: *h*, Dorsolateral aspect of 4.6 mm. specimen; *i*, antenna 2 showing segmented flagella and the squame; *j*, thoracic limbs 4 and 5. *k–m*, Stage V: *k*, Anterodorsal aspect of 5.5 mm. specimen; *l*, antenna 2, endopod and squame; *m*, telson and uropods.

There are 5 setose pleopods, 5 terminal spines on the telson, and the endopod of antenna 2 is segmented (Fig. 15*i*). The rostral plate (Fig. 15*h*) is more triangular, with less convex margins than in Stages II or III, and it has a small terminal spine. There is a pronounced dorsal organ on the carapace. The squame of antenna 2 is differentiated; it is setose on its inner margin and without a distolateral spine; the spine arising from the basal segment is present. The segmented endopod is beginning to elongate. The first abdominal somite possesses tergal wings. Thoracic limb 1 is bifurcate distally; the second and third limbs are fully segmented, and each has a setose exopodite and a gill. Limb 4 (Fig. 15*j*) is 3- or 4-segmented, with a rudimentary exopodite which has 2 setae, and a rudiment of a gill. Limb 5 (Fig. 15*j*) is short, kneed, with a terminal seta, and rudiments of gill and exopodite; limb 6 is rudimentary.

FURCILIA, STAGE V: (Fig. 15*k–m*). Length, 5.0 to 6.1 mm. (average, 5.4 mm., 15 specimens measured).

This stage has 3 (rarely 2) terminal spines on the telson. The rostral plate (Fig. 15*k*) is triangular, almost straight sided, with a minute terminal spine. The spine on segment 1 of antenna 1 is somewhat longer than the second segment of the peduncle (Fig. 15*k*). The endopodite of antenna 2 is segmented and the squame is as long as the endopod. Limbs 1 to 4 are better developed than in the previous stage; limb 5 is segmented, short and kneed; limb 6 is a kneed rudiment which may be segmented. The telson is 5 times as long as wide (Fig. 15*m*) and the inner post-lateral spines are becoming conspicuously broadened. The outer uropod is as long as the inner and they reach almost to the base of the outer pair of post-lateral spines.

FURCILIA, STAGE VI: Length, 5.0 to 6.0 mm. (average 5.6 mm., 15 specimens measured).

There is one terminal spine on the telson (rarely 2). The rostral plate is broadly triangular and acutely pointed. The spine on segment 1 of antenna 1 is usually present and extends almost to the end of segment 2 of the peduncle. The endopod of antenna 2 has 3 segments, and there are indications of the segmentation of the flagella in the terminal segment. Thoracic limb 5 has a 3-jointed tarsus; limb 6 is kneed, with 2 segments and elements of exopodite and gill; limb 7 is a bud with a gill, and there is a single gill rudiment at the position of limb 8. The telson is slender and the outer post-lateral spines are much reduced, the middle pair are long and slender, the inner pair are broadened proximally, and curve outward in the distal half. The uropods are subequal in length and reach to the base of the post-lateral spines; the inner has 4 to 6 setae on its outer margin.

POST LARVAL STAGE: (Fig. 16). The specimen figured (Fig. 16*a*) is 7.5 mm. long and was readily identifiable as *E. lucens*. The terminal portion of the telson (Fig. 16*b*) is acutely pointed and has one pair of large latero-terminal spines which bear small secondary spines distally. Inner and outer uropods are equal in length, but are not as long as the telson. There is a pre-anal spine with 2 teeth. Antenna 1 (Fig. 16*c*) is developing a keel on segment 3 and a small, distinct, triangular lappet on segment 1. The squame of antenna 2 (Fig. 16*c*) is longer than the combined segments 1 and 2 of the peduncle of antenna 1, and has a long spine at the base. The rostrum is proportionately longer and more acutely pointed than that of the adult. The thoracic limbs are as in the adult, including the modified setae on the distal segment of limb 2 (Fig. 16*d*). The mandible has a well-developed cutting plate and palp, and maxillae 1 and 2 are similar to those in the adult.

Development of Nyctiphanes australis

Sheard (1953) reviews the state of knowledge on the development of *Nyctiphanes australis*, and presents a series of detailed diagrams illustrating variation in the order of development of pleopods, and in the loss of

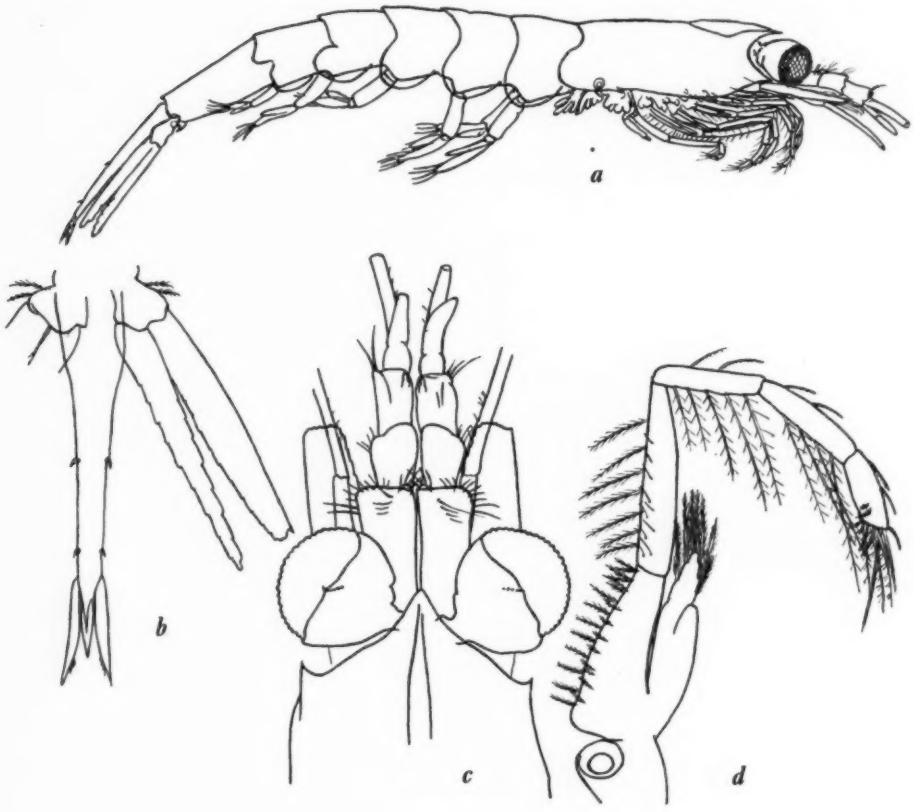


FIG. 16. Mid post-larval stage of *Euphausia lucens*. *a*, Lateral aspect of 7.5 mm. specimen; *b*, telson and uropods; *c*, anterodorsal aspect; *d*, second thoracic limb.

telsal spines. In this, as in previous accounts of development in this species, little attention has been paid to other morphological changes. Inasmuch as morphology is necessary for the certain identification of the larvae of *N. australis*, the present account deals with this, especially of the thoracic limbs and their differentiation during the furcilia stages. The account is not exhaustive, but is representative of a range of instars from each of the furcilia stages. The designation of the furcilias, and the instars composing them, are those proposed by Sheard; the present material, although restricted in quantity, suggests that his furcilia stages meet the requirements of this species.

By means of his diagrams Sheard demonstrates that the number of instars preceding some later instar (for example, that with 5 setose pleopods and 7 terminal spines on the telson) may vary. This condition has not been otherwise commented on, although the present material suggests that it is important. It appears to lead to variations in the degree of differentiation of the thoracic limbs and antennae among specimens which have been

designated a single instar by other characters. This occurs in the later instars of Furcilia II, and in Furcilia III instars. Thus in the "Lachlan" material, the instar with 4 setose and one non-setose pleopods is composed of two groups of specimens, one of which is further advanced than the other in its limb development, probably because specimens have undergone an additional earlier ecdysis. It is possible that further groups could have been identified from more extensive material. Sheard recognises that the group of specimens with 5 setose pleopods and 7 terminal spines on the telson is comprised of individuals from two instars. One of these, in which the endopod of antenna 2 is not segmented and the inner post-lateral spine of the telson is not broadened, he identifies as belonging in Furcilia II (his 5S7Sp A); the other, wherein the endopod is segmented and the inner post-lateral spine is broadened, is assigned to Furcilia III (his 5S7Sp B). In "Lachlan" specimens a third group, belonging in Furcilia II (and which, in itself, may have been a miscellany of development stages), is present. These specimens were intermediate between Sheard's two groups in their limb and antennal development, but retained the pleopod and telsal differentiation typical of this group of instars (5 setose pleopods, 7 terminal spines on the telson).

This type of complexity extends into the other instars of Furcilia III. It is convenient to identify those instars in which multiple stages of limb development are present as "instar-groups," while each of the stages composing such a group is an instar. This classification possibly has a factual basis, although insufficient material has defeated attempts to trace the development paths leading up to these complexities. However, Sheard's diagrams of development series for *N. australis* suggest possibilities which might produce such a result. More will be said of this type of parallelism in development in the discussion of Furcilias II and III in the following.

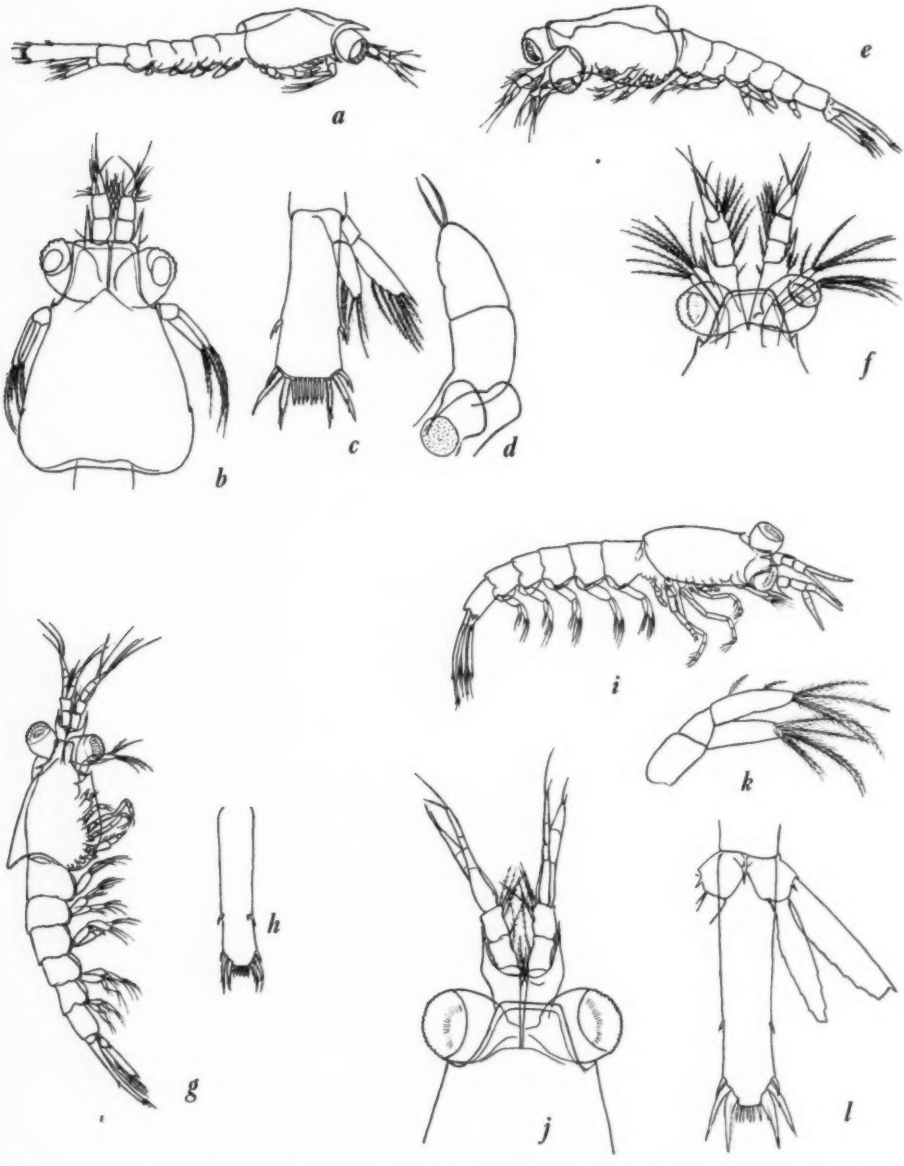
FURCILIA, STAGE I: (Fig. 17*a–d*). The number of pleopods and telsal spines present and the size of all specimens in the "Lachlan" material are given in Table 4. In all instars of this stage the pleopods are non-setose.

The morphological changes between successive instars are progressive, but not extensive. The wide frontal plate of the carapace (Fig. 17*b*) covers approximately half the eye and stalk, is broader basally than long, and is squarely truncate anteriorly. The carapace is medially emarginate posteriorly and has a denticle on each lateral margin; stout anteroventral spines are present. The telson (Fig. 17*c*) has 7 terminal spines, 1 pair of lateral and 3 pairs of post-lateral spines. The ratio of length of telson to its width ranges between 2:1 for specimens with one pair of pleopods to 7:3 for specimens with four pairs; the telson is twice the length of the sixth abdominal somite and the lateral spines are placed at between one-half and two-thirds its length.

The thoracic limbs develop progressively with each instar, and those already differentiated increase in complexity. Limb 1 is biramous throughout the instars, the inner ramus (endopod) being 2-segmented. Limb 2 develops from a stout, unsegmented, kneed rudiment to a kneed, 3-segmented structure with elements of a gill and exopodite. Limb 3 grows from a bud to an elongate rudiment with exopodite and gill as bud-like swellings; limb 4 is an elongated bud in the 4-pleopod instar. The distal spine of the basal segment of the peduncle of antenna 1 (Fig. 17*b*) reaches beyond the mid-length of segment 3; both flagellal rudiments are segmented off at instar 2, but only the inner in the first instar.

FURCILIA, STAGE II: (Fig. 17*e–l*).

Table 5 presents the data on pleopods and telsal spines and size of the "Lachlan" material and demonstrates that specimens with 4 setose and 1 non-setose and those with 5 setose pleopods and with 7 terminal telsal spines are 'instar-groups,' not single instars. Two instars, identified by differing states of



[5] FIG. 17. Furcilia stages of *Nyctiphanes australis* G. O. Sars. *a–d*, Stage I with 4 non-setose pleopods: *a*, Lateral aspect of 2.9 mm. specimen; *b*, anterodorsal aspect; *c*, telson and uropods; *d*, rudimentary limb 2. *e*, *f*, Stage II with 3 setose and 2 non-setose pleopods: *e*, Dorsolateral aspect of 3.5 mm. specimen; *f*, anterodorsal aspect. *g*, *h*, Instar A, Stage II, from the instar-group with 5 setose pleopods and 7 terminal spines on the telson: *g*, Dorsolateral aspect of 4.2 mm. specimen; *h*, telson. *i–l*, Instar A′, Stage II, from the instar-group with 5 setose pleopods and 7 terminal spines on the telson: *i*, Dorsolateral aspect of 4.3 mm. specimen; *j*, anterodorsal aspect; *k*, unsegmented antenna 2; *l*, telson and uropods, inner post lateral spines of telson broadening proximally.

TABLE 4

COUNTS AND MEASUREMENTS OF STAGE I FURCILIAS OF *Nyctiphanes australis*

NUMBER OF PLEOPODS	TELSAL SPINES	NUMBER OF SPECIMENS	RANGE OF LENGTH, MM.	AVERAGE LENGTH, MM.
1	7	1	2.5	....
2	7	2	2.5	....
3	7	13	2.5 to 2.8	2.7
4	7	33	2.7 to 3.0	2.8

TABLE 5

COUNTS AND MEASUREMENTS OF STAGE II FURCILIAS OF *Nyctiphanes australis*

NUMBER OF SETOSE(S) AND NON-SETOSE(N) PLEOPODS	TELSAL SPINES	NUMBER OF SPECIMENS	INSTAR GROUP	LENGTH RANGE, MM.	AVERAGE LENGTH, MM.
1S 3N	7	1	....	3.1	....
3S 2N	7	20	....	3.1 to 3.8	3.6
4S	7	1	....	3.6	....
4S 1N	7	23	1	3.4 to 3.8	3.6
		17	2	3.4 to 3.6	3.5
5S	7	24	A	3.6 to 4.2	3.9
		23	A′	4.0 to 4.7	4.3

limb development are in the first group. In the second, two of three instars are listed (Figs. 17*g*, *h*, instar A; 17*i–l*, instar A′); these belong in Furcilia II as in neither is the endopod of antenna 2 segmented (Fig. 17*k*), but the third instar has the segmented endopod and is listed in Furcilia III.

Throughout all instars, the frontal plate remains broad-based, more or less squarely truncate and covers a considerable portion of eye and stalk (Fig. 17*j*). The laterodistal spine on segment 1 of antenna 1 persists, reaching from two-thirds to almost the outer end of segment 3 of the peduncle; the flagellae are initially about twice the length of those in the last instar of Furcilia I, but are elongate and slender by the final instar of Furcilia II (Fig. 17*j*). A pair of dorsolateral tergal wings appear on the first abdominal segment in the first instar (Fig. 17*e*) and persist throughout the instars of this and Furcilia III. The telson (Fig. 17*h*, *l*) remains twice as long as the sixth abdominal segment; the ratio of length, to the width at the distal extremity, changes from 3:1 to 4:1 and that of length of telson to the length from its base to the lateral spines changes from 5:3 to 4:3, by the end of the series. The inner uropods reach about two-thirds the way to the lateral spines in the first, and all of the way in the final, instar.

Of the thoracic limbs (Fig. 17) the endopod of limb 1 commences to elongate relative to the exopod at the instar with 4 setose pleopods. At that with 1 setose and 3 non-setose pleopods limb 2 is 3-segmented, with 2 terminal setae and clearly defined buds of gill and exopodite; by the 4 setose pleopod stage the tarsal segment is 3-jointed (i.e., with 3 subsegments) and the limb is moderately setose, has a 2-branched gill and a stout exopodite. Limb 3 progresses from an elongate rudiment to a 3-segmented, stout appendage, with 2 terminal setae, a single gill and a small, stump-like exopodite. Limb 4 becomes an elongate kneed rudiment.

The instars comprising the instar-groups with 7 telsal spines and either 4 setose and 1 non-setose or 5 setose pleopods (Fig. 17) are differentiated by the degree of development reached by the thoracic limbs; relevant data

TABLE 6

COMPARISON OF LIMB DEVELOPMENT AMONG INSTARS OF THE INSTAR-GROUPS POSSESSING 7 TERMINAL SPINES ON THE TELSON AND EITHER 4 SETOSE AND 1 NON-SETOSE OR 5 SETOSE PAIRS OF PLEOPODS IN *Nyctiphanes australis*

LIMB NUMBER	CHARACTER	FURCILIA II				FURCILIA III
		With 4 Setose and 1 Non-setose Pleopods		With 5 Setose Pleopods		With 5 Setose Pleopods
		Instar 1	Instar 2	Instar A	Instar A′	Instar B
2	Segments, general	Complete, 3 tarsal joints	Complete	Complete		
	Setae	Sparse, overall	Moderate	Moderate	Fully developed	Fully developed limb
	Exopod	Well developed bud, no setae	2 terminal setae	2 terminal setae	.....	Setose
	Gill	2-branched	2-branched	2-branched	.....	.....
3	Segments, general	3-segmented; tarsal joints indistinct	Tarsus 3-jointed	Tarsus 3-jointed	Fully developed	Fully developed, and almost as long as limb 2
	Setae	2, terminal	Moderate, overall	Moderate–strong, overall	Strongly setose	.....
	Exopod	Well developed bud	Non-setose	Non-setose	Terminal setae	.....
	Gill	2-branched	2-branched	2-branched	.....	.....
4	Segments, general	Kneed, indistinct 2 segments	Stout, 3-segmented	3-segmented	Tarsus 3-jointed	Fully segmented, well developed; about half as long as 2
	Setae	.....	Terminal	Terminal	Moderate, overall	Moderate–strong
	Exopod	Rudiment	Large bud	Large (elongate) bud	Non-setose	With single terminal seta
	Gill	Well developed bud	2-branched	2-branched	2-branched	.....
5	Segments, general	Elongate bud	Elongating, kneed rudiment	Elongate, kneed rudiment	2–3 segmented	3-segmented
	Setae	.....	.....	.....	2, terminal	Sparse on terminal segment
	Exopod	.....	Large bud	Large bud	Elongate bud	Elongate, rudimentary
	Gill	Bud	2-branched	2-branched	2-branched	2-branched
6	Segments, general	Bud	Elongating rudiment	Elongate rudiment	Unsegmented, kneed rudiment	Elongate, kneed rudiment
	Setae	.....	.....	.....	.....	Non-setose
	Exopod	.....	.....	.....	.....	.....
	Gill	.....	Bud	Elongate bud	Single	2-branched
7	General	Bud	Bud	Bud	Bud, increasing in length	Elongate bud; 2-branched gill

are summarised in Table 6 (see also Table 9).

It is seen that the degree of differentiation in instar 2 and instar A (Fig. 17*g*, *h*) is similar. This is possibly due to the same number of ecdyses having been passed in the development paths of these two (different) instars. Contrarily, several degrees of development in each of the two instar-groups suggest that additional ecdyses are necessary during the course of development of some specimens, to attain this end.

FURCILIA, STAGE III: (Fig. 18).

Table 7 presents data on the "Lachlan" specimens of this stage.

The tergal wings (Fig. 18*a*, *g*) on the first abdominal segment persist throughout the series of instars. The frontal plate of the carapace gradually narrows at the base, but is still comparatively broad; the front margin becomes broadly rounded in the later instars. The uropods elongate and become slender and reach a little beyond the lateral spines. The telsal length to width (at the tip) attains the ratio of 6:1; by the last instar the outer post-lateral spines are much reduced, the middle pair are slender and beginning to reduce and the inner are long and broad; the telson is round ended with a short, acute spine.

The squame (Fig. 18*f*, *h*) is strongly setose on its inner margin and develops a disto-lateral spine. The flagellae of antennae 1 and 2 increase in length until they are about three times the length of the peduncles. The disto-lateral spine of segment 1 of antenna 1 persists. At the stage of instar E, a wing-like expansion begins to develop dorsolaterally on the distal end of segment 1, antenna 1; this has increased in size by instar F, and from instar K onwards is a conspicuous, triangular lappet.

As in Furcilia II the individual instars of the instar-groups are identifiable by the state of differentiation of the limbs; and again there is duplication in the degree of limb development between one or more instars of one group and some of the following (except that no overlap was apparent between the groups with 5 and 3 telsal spines).

The stage of development of limbs 5, 6 (Fig. 18*d*, *e*), and 7 are of chief concern for identifying the instars of each group, and data are tabulated in Table 8 for those instar-groups with 5, 3 and 1 telsal spines.

The interrelationships between instars of one group and those of another are illustrated in Table 9. In this, those instars of one group which show identical limb development with those in another are linked by dashed lines; as well, an instar arising directly from a previous one is connected to it by a solid line. It is apparent that relationships are complex,

TABLE 7

COUNTS AND MEASUREMENTS OF STAGE III FURCILIAS OF *Nyctiphanes australis*

NUMBER OF SETOSE PLEOPODS	NUMBER OF TELSAL SPINES	NUMBER OF SPECIMENS	INSTAR	LENGTH RANGE, MM.	AVERAGE LENGTH, MM.
5	7	17	B	4.3 to 4.8	4.5
5	6	2	....	.....	....
5	5	13	C	4.4 to 5.0	4.6
		13	D	4.4 to 4.6	4.6
		14	E	4.3 to 5.2	4.9
5	4	2	....	.....	....
5	3	13	F	4.9	4.9
		14	G	5.0 to 5.7	5.2
5	2	6	....	.....	....
5	1	13	H	4.4 to 5.0	4.8
		14	J	5.3 to 5.7	5.4
		14	K	5.4 to 6.5	5.9

TABLE 8

LIMB DIFFERENTIATION OF INDIVIDUAL INSTARS OF FURCILIA III, *Nyctiphanes australis*

INSTAR	NUMBER OF TELSAL SPINES	THORACIC LIMB			OTHER CHARACTERS
		5	6	7	
B.....	7	See instar B, Table 6			
C.....	5	Limb development as for instar	B, Table 6		
D.....	5	Stout, sparsely setose; tarsus 3-jointed; exop. non-setose; 3-branched gill	Kneed, 2–3 segments, non-setose. No exop.; 2-branched gill	Bud; 2-branched gill	
E.....	5	Fully developed; ⅗ length of limb 4; exop. non-setose	Tarsus 3-jointed; limb sparsely setose; small bud-like exop. occasionally; 2-branched gill	Elongate, kneed rudiment; 2-branched gill	Wing-like extension dorso-laterally on distal end seg. 1 of antenna 1
*F.....	3	Exopodite with terminal seta	Limb 3-segmented, sparsely setose; 2-branched gill	Elongate bud; 2-branched gill	Extension on seg. 1, ant. 1, more advanced than E; stout, forwardly curving protrusion
†G.....	3	Exopodite with terminal setae	Tarsus 3-jointed; limb moderately setose; 3-branched gill	2-segmented, single terminal seta; 2–3–branched gill	Extension on seg. 1, ant. 1, becomes a triangular, forwardly curving flap-like protrusion
*H.....	1	Twice length of limb 6; exopodite with terminal seta	3-segmented, sparsely setose, 2-branched gill	Elongate bud; gill 2-branched	Ant. 1, segment 1 as for instar F
†J.....	1		Tarsus 3-jointed; limb moderately setose; 3-branched gill; (exop. in young males)	2-segmented with or without setae; 2–3–branched gill	Ant. 1 segment 1 as for instar G
K.....	1		Fully developed, strongly setose; no exop., or exop. with terminal setae (males)	Moderately setose, half length of limb 6; no exopodite	Extension on seg. 1, ant. 1, now a conspicuous lappet

*Denotes identity in limb development between instars F and H.
†Denotes identity in limb development between instars G and J.

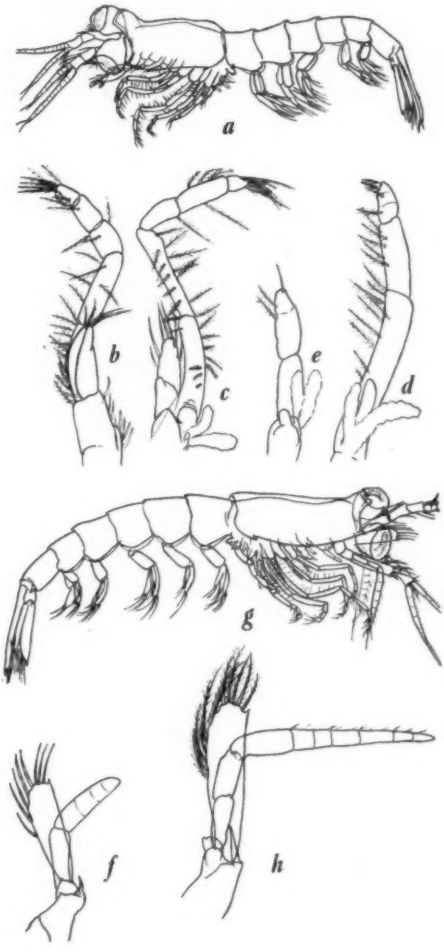


FIG. 18. Two instars of Furcilia Stage III of *Nyctiphanes australis* G. O. Sars. *a–f*, Instar D, from the instar-group with 5 telsal spines: *a*, Dorsolateral aspect of 4.5 mm. specimen; *b*, *c*, *d*, *e*, thoracic limbs 1, 2, 5, 6; *f*, antenna 2. *g*, *h*, Instar F, from the instar-group with 3 telsal spines: *g*, lateral aspect of 4.9 mm. specimen; *h*, antenna 2.

but that the table illustrates only a portion of the picture. For example there is no indication of the origin of either instars B or E, or of the fates of instars A or C. Much more material than was available to me is necessary to complete the developmental paths indicated by the table. Sheard's (1953) diagrams again demonstrate possible paths.

It seems probable that the instar-groups, with their instars having differing degrees of limb development, must arise from specimens undergoing additional ecdyses in Furcilia I or early in Furcilia II. It is perhaps noteworthy that the first indication of an instar-group is among specimens with 4 setose and 1 non-setose pleopods at a later stage of Furcilia II. It is probable that developmental paths following different courses (i.e., paths involving different combinations of setose and non-setose pleopods) first come together in this late stage of Furcilia II. Thenceforth specimens of the several instars would develop along parallel lines until maturity is reached.

Development of Thysanoessa gregaria

Gurney (1947) described the development of *Th. gregaria* from the first furcilia to the fifth cyrtopia from material collected around Bermuda. The first three of Gurney's five furcilias were obtained in the New Zealand material. A detailed comparison of these with the descriptions of those from Bermuda reveals only slight differences in the proportion of length to breadth of the telson and in the lengths of the second to fourth lateral spines (the post-laterals) on the telson. In Furcilia I, Gurney states the telson is three times as long as wide, and "spine 4 not generally longer than spine 3, and rarely as long as the telson is wide"; in the New Zealand specimens the telson may be 3.5 times as long as wide and the spines are longer than the width of the telson. In other characters such as the form and extent of the rostral plate, number and position of spines on the telson, degree of limb development, proportional lengths of segments of antenna 1, and in the pleopod development, there are no discernible differences.

According to Gurney, *Thysanoessa gregaria* differs from the other species of the genus in

TABLE 9

RELATIONSHIPS OF INSTARS IN THE 'INSTAR-GROUPS' OF FURCILIA STAGES II AND III, *Nyctiphanes australis*
(Explanation in Text)

FURCILIA CHARACTERS	FURCILIA STAGES AND CHARACTERS					
	II 4S 1N	II and III 5S 7Sp	III 5Sp	III 3Sp	III 1Sp	Post Larval*
Instars	1 → A 2 → A′ ? B	C D E	F - - - - - - - H → G - - - - - - J → ? K			+2 extra moults +1 extra moult

*Post larval stage: the number of extra moults that are considered necessary for specimens to undergo in order to reach a stage of development comparable with those of instar K (the most advanced) are indicated.
Abbreviations of characters: S—setose pleopods; N—non-setose pleopods; Sp—terminal telsal spines.

having the rostral plate pointed from Furcilia Stage I and in the reduction in number of telsal spines during Stage IV. Appropriate furcilia stages were not available from the local collections to check the latter character, but the form of the rostral plate was similar in the earlier stages.

There was no morphological variation among the specimens examined.

Einarsson (1945) has summarised previous expressions of opinion on and added considerably more evidence towards the view that neritic euphausiid species show much greater variation in the morphological features of the larval instars than do oceanic species. The large range of instars so far demonstrated for the typically neritic species of *Nyctiphanes* (Sheard, 1953; Boden, 1951, 1955; and others) concurs in this, as do the small numbers of well-defined (dominant) instars for the southern and oceanic *Euphausia* species (John, 1936; Fraser, 1936). However, Sheard maintains that dominant instars do not necessarily obtain in either neritic species, e.g., *N. australis*, where there may be numerous instars, or in oceanic species, e.g., *Euphausia simplex*, where there are fewer instars. He regards the so-called dominant instars of *N. australis* as being significant only in local stocks, with the distinguishing characteristics of such dominants varying from place to place as environmental conditions change. By studying collections covering the ecological range of the species these locally occurring 'dominants' become submerged in a life-history series which in overall view is characterised by a diffuse variety of instars. Boden (1955) questions this viewpoint of indeterminate dominants.

The "Lachlan" collections of *N. australis* are small. Nevertheless, a variety of the instars which may occur were available. In that the material is from a restricted environmental range and, therefore, is essentially a local stock, the apparent dominant instars in Furcilias I, II, and III could conform to Sheard's view of the local origin of such dominants. The New Zealand material exhibits the additional complexity of the 'instar-group' wherein characters, which have been regarded as signifying a particular instar, are found to

include what appears to be a number of instars; these are separable on the several degrees of differentiation reached by the thoracic appendages. The orderliness, and interrelationships between the instars of these instar-groups (Table 9), seem to preclude the possibility that the instars are composed of specimens in which morphological variations have arisen due to changes in such environmental factors as temperature.

The larval development of two oceanic species, *Euphausia lucens* and *Thysanoessa gregaria*, presents an opposing view to that expressed by Sheard (1953) from his studies of *N. australis* and *E. simplex*. In *E. lucens* morphological variants were recorded only as rare exceptions in an orderly series of closely diagnosed instars; nor were there any indications of the instar-groups of *N. australis*. There were no variants in the material for *T. gregaria*. Dominant stages were undoubtedly present in both (see Table 10 for *E. lucens*). This may have been due to inadequate sampling (Sheard, 1953); nevertheless, there is general conformity in the larval histories of a number of oceanic species, in that there are small numbers of well defined instars. This suggests that those instars deviating from the usual expression of an oceanic species' life history may be regarded as exceptional to the dominant instars.

DIURNAL VARIATION IN NUMBERS OF EUPHAUSIIDS AT THE SURFACE

Little information on the diurnal movements of southern euphausiids is available. Tattersall (1924) reported of "Terra Nova" samples that numbers taken at night were much greater; he also (1936*a*) described the vertical distribution during daylight of one species at two stations near the Great Barrier Reef. Hardy and Gunther (1935) discuss and illustrate vertical movements for various developmental stages of *Euphausia superba* and for *E. frigida*, *E. triacantha*, *E. vallentini*, and species of *Thysanoessa* from South Georgia. For the Northern Hemisphere, Esterly (1914*b*) discusses vertical distribution and movements of euphausiids in the Californian area; Leavitt (1935, 1938) extensively discusses vertical distribution of species, and Moore (1949, 1950) illustrates vertical distribution and migration for the Bermuda area.

Vertical distribution cannot be demonstrated for the present collections since no vertical hauls were taken. The fact of diurnal migration is apparent, however, through the diurnal variation of numbers taken in surface tows, both in the station series 74 to 85 in western Foveaux Strait, and the curves constructed for all other surface tows. In Figure 7 the catch per tow for *Euphausia lucens*, *Nyctiphanes australis*, and *Thysanoessa gregaria* is expressed as a percentage of the whole catch of each species for stations 74 to 85 (see also for mysids, the curves for two species of which are included). Both *E. lucens* and *T. gregaria* arrive at the surface in large numbers at 2300 hours, an hour before *N. australis*, and more or less maintain these numbers until 2400 hours when they, together with *N. australis* disperse, leaving many fewer specimens

TABLE 10
DOMINANCE IN FURCILIA STAGES OF *Euphausia lucens*

PLEOPOD DEVELOPMENT	TELSAL SPINES	ANTENNA 2, ENDOPODITE	NUMBER OF SPECIMENS	AVERAGE LENGTH, MM.	FURCILIA STAGE
4 non-setose	7	Unsegmented	43	3.0	I
4 setose, 1 non-setose	7	Unsegmented	70	3.8	II
5 setose	5	Unsegmented	44	4.7	III
5 setose	6	Unsegmented	2	....	III
5 setose	5	Segmented	16	5.2	IV
5 setose	3	Segmented	17	5.4	V
5 setose	1	Segmented	16	5.6	VI
5 setose	2	Segmented	2	....	VI

to be taken in the tow at 0100 hours. At 0200 hours, and accompanying a similar rise for mysids, there is a sharp increase in numbers of *N. australis* and *T. gregaria*, but for *E. lucens* there is only a check to the rate of decrease of numbers being taken. As was discussed for the mysids, the factors contributing towards this second rise (at 0200 hours) are not understood. Nevertheless, there are similarities between this curve and that obtained for all other stations (Fig. 19). The main rise commences at 2100 hours and reaches a peak at 2300 hours in both; an absence of specimens at 2400 hours (in Fig. 19) probably corresponds with the 0100 hours decrease in collections from stations 74 to 85. This is succeeded by a rapid increase over the next hour to 0100 hours, an hour earlier than for stations 74 to 85, when again there is a fairly rapid decrease, then a check at 0300 hours (corresponding to the pre-dawn rise?) and the final dispersion due to the dawn descent. A catch of 732 specimens at station 308 at 0500 hours (indicated in Fig. 19 by the dashed line) falls outside the normal pattern and may be the result of sampling a swarm which has persisted through to daylight.

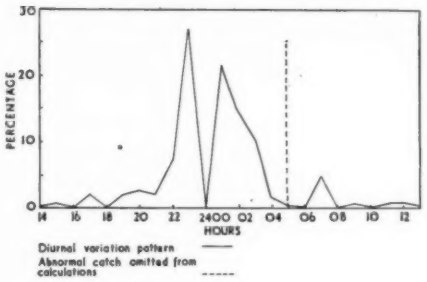


FIG. 19. Diurnal variation in surface waters for all species of euphausiid for the period January through March, 1951. The catch for each hour is expressed as a percentage of the total of all specimens captured.

SUMMARY

Collections were made from the survey frigate, H.M.N.Z.S. "Lachlan," between Wellington and the southern extremity of South Island during January, February, and March, 1951, and between southern New Zealand and Auckland and Campbell islands in November, 1951. In all, 86 stations representative of this coverage have been examined and the mysid and euphausiid fauna reported on.

Two species of mysid, *Tenagomysis macropsis* and *T. tenuipes* were collected about Foveaux Strait; this extends the range of *T. tenuipes* 200 miles northward from Auckland Islands. The collections of *T. macropsis* slightly extend the area from which it has been taken previously. *T. tenuipes* was originally described from a single male from the Auckland Islands; the present material has afforded the opportunity of reporting on and adding to the systematic morphology of males and females. For both species the larval development, which is continuous, has been described.

Five species of euphausiid were taken; four, namely *Euphausia lucens*, *E. vallentini*, *Thysanoessa gregaria*, and *Nyctiphanes australis* had been recorded previously, but one, *Nematoscelis megalops* (?) is a new record for the southern Pacific.

The larval development stages of *Euphausia lucens* have been described. From a comparison of these with early stages described as *E. lucens* from South Africa, the writer concludes that the latter account is of another species. Instars of the three furcilia stages of *Nyctiphanes australis* are described. It has been found that some of the 'instars,' previously designated by certain morphological characters, in reality appear to be groups of instars in which the individual instars are identifiable by the degree of differentiation reached in the thoracic appendages. The first three stages obtained for *Thysanoessa gregaria* show that its development in New Zealand waters closely parallels that of Bermudan material.

Data are presented on the distribution of both the mysids and euphausiids about New Zealand.

The diurnal variation of numbers at the surface indicates that a vertical migration oc-

curs for mysids and euphausiids which follows the pattern for other zooplanktonic organisms. Differential migration between adults and larval *Tenagomysis macropsis* has been recorded.

This investigation was carried out as a part of a wider survey of southern New Zealand zooplankton during my service in the New Zealand Defence Scientific Corps, attached to the Royal New Zealand Navy. Laboratory facilities were provided at Victoria University College by Professor L. R. Richardson, head of the Department of Zoology for which, and for whose supervision of this study, I am most grateful. I am also most appreciative of the service extended by Dominion Chemical Laboratory for making salinity determinations, and to Mr. W. H. Dawbin for reading the proofs of this paper.

REFERENCES

BANNER, A. H. 1949. A taxonomic study of the Mysidacea and Euphausiacea (Crustacea) of the northwestern Pacific. *Roy. Canad. Inst., Trans.* 28(1), No. 58: 2–64.

BODEN, B. P. 1951. The egg and larval stages of *Nyctiphanes simplex*, a euphausiid crustacean from California. *Zool. Soc. London, Proc.* 121(3): 515–527.

——— 1954. The euphausiid crustaceans of southern African waters. *Roy. Soc. So. Africa, Cape Town, Trans.* 34(1): 181–243.

——— 1955. Euphausiacea of the Benguela Current, first survey, R.R.S. 'William Scoresby,' March 1950. *Discovery Reports* 27: 337–376. Cambridge University Press, London; issued by National Institute of Oceanography, U.K.

BODEN, B. P., M. W. JOHNSON, and E. BRINTON. 1955. The Euphausiacea (Crustacea) of the North Pacific. *Calif. Univ., Scripps Inst. Oceanogr., Bul.* 6(8): 287–400, 55 figs.

CHILTON, C. 1911. Scientific results of the New Zealand Government Trawling Expedition 1907. *Canterbury Mus., Rec.* 1(3): 301–303.

——— 1926. The New Zealand Crustacea Euphausiacea and Mysidacea. *New Zeal. Inst., Trans. and Proc.* 56: 519–522.

CUSHING, D. H. 1951. The vertical migration of planktonic Crustacea. *Biol. Rev.* 26(2): 158–192.

DAKIN, W. J., and A. N. COLEFAX. 1940. The plankton of Australian coastal waters off New South Wales, Part I. *Sydney Univ., Dept. Zool., Pubs.* Monog. 1: 1–215.

DEACON, G. E. R. 1937. The hydrology of the Southern Ocean. *Discovery Reports* 15: 1–124. Cambridge University Press, London; issued by Discovery Committee, London.

EINARSSON, H. 1942. Notes on Euphausiacea I–III. *Dansk Naturhist. For. Kjøbenhavn, Vidensk. Meddel.* 106: 263–286.

——— 1945. Euphausiacea I. Northern Atlantic species. *Dana Report* 27: 1–185. Carlsberg Foundation, Copenhagen.

ESTERLEY, C. O. 1914*a*. The Schizopoda of the San Diego Region. *Calif. Univ., Pubs., Zool.* 13(1): 1–20.

——— 1914*b*. The vertical distribution and movements of the Schizopoda of the San Diego Region. *Calif. Univ., Pubs., Zool.* 13(5): 123–145.

FRASER, F. C. 1936. On the development and distribution of the young stages of krill (*Euphausia superba*). *Discovery Reports* 14: 1–192. Cambridge University Press, London; issued by Discovery Committee, London.

GURNEY, R. 1947. Some notes on the development of the Euphausiacea. *Zool. Soc. London, Proc.* 117(1): 49–64.

HANSEN, H. J. 1905. Further notes on the Schizopoda. *Inst. Océanogr., Bul.* 42: 1–32. [Not seen.]

——— 1910. The Schizopoda of the Siboga Expedition. *Siboga Exped.* Monog. 37: 1–123.

——— 1911. The genera and species of the order Euphausiacea, with account of remarkable variation. *Inst. Océanogr., Bul.* 210: 1–54.

——— 1912. The Schizopoda. *Harvard Univ., Mus. Compar. Zool., Mem.* 35(4): 175–296.

——— 1913. On some Californian Schizopoda. *Calif. Univ., Pubs., Zool.* 11(9): 173–180.

——— 1915. The Crustacea Euphausiacea of the United States National Museum. *U. S. Natl. Mus., Proc.* 48: 59–114.

HARDY, A. C., and E. R. GUNTHER. 1935. The plankton of the South Georgia whaling grounds and adjacent waters. *Discovery Reports* 11: 1–456. Cambridge University Press, London; issued by Discovery Committee, London.

HOLT, E. W. L., and W. M. TATTERSALL. 1906. Preliminary notice of the Schizopoda collected by H.M.S. "Discovery" in the Antarctic Region. *Ann. and Mag. Nat. Hist.* VII, 17: 1–11.

II, N. 1937. Studies in Japanese Mysidacea III. Descriptions of four new species belonging to tribes Leptomysini and Erythropini. *Jap. Jour. Zool.* 7: 191–209.

JOHN, D. D. 1936. The southern species of the genus *Euphausia*. *Discovery Reports* 14: 193–324. Cambridge University Press, London; issued by Discovery Committee, London.

LEAVITT, B. B. 1935. A quantitative study of the vertical distribution of the larger zooplankton in deep water. *Biol. Bul.* 68: 115–130.

——— 1938. The quantitative vertical distribution of macrozooplankton in the Atlantic Ocean Basin. *Biol. Bul.* 74: 376–394.

MOORE, H. B. 1949. The zooplankton of the upper waters of the Bermuda area of the North Atlantic. *Bingham Oceanogr. Collect., Bul.* 12(2): 2–97.

——— 1950. The relation between the scattering layer and the Euphausiacea. *Biol. Bul.* 99(2): 181–221.

NOUVEL, H. 1942. Diagnoses préliminaires de Mysidacés nouveaux provenant des Campagnes du Prince Albert Ier de Monaco. *Inst. Océanogr., Bul.* 831: 1–11.

REGAN, C. T. 1914. Fishes. *Brit. Antarc. (Terra Nova) Exped. 1910. Nat. Hist. Rpts., Zool.* I(1): 1–54. British Museum (Natural History), London.

SARS, G. O. 1883. Preliminary notices on the Schizopodâ of H.M.S. "Challenger" Expedition. *Vidensk. Selsk. Christiania, Forhandl.* 7: 1–43. [Not seen.]

——— 1885. Report on the Schizopoda collected by H.M.S. "Challenger" during the years 1873 to 1876. *Challenger Reports, Zool.* 13: 1–225. H.M. Stationery Office, London.

SHEARD, K. 1953. Taxonomy, distribution and development of the Euphausiacea (Crustacea). *B.A.N.Z. Antarc. Res. Exped. 1929–31. Reports, Ser. B. (Zool. and Bot.)* 8 (1): 1–72, tables 1–17, text-figs. 1–17.

STEBBING, T. R. R. 1900. On some crustaceans from the Falkland Islands collected by Mr. Rupert Vallentin. *Zool. Soc. London, Proc.* 1900, 517–568.

TATTERSALL, OLIVE S. 1955. Mysidacea. *Discovery Reports* 27: 1–190. Cambridge University Press, London; issued by National Institute of Oceanography, U.K.

TATTERSALL, W. M. 1918. Euphausiacea and Mysidacea. *Australasian Antarc. Exped. 1911–14. Sci. Reports, Ser. C. Zool. and Bot.* 5(5): 1–15. William Applegate Gullick, Government Printer, Sydney.

——— 1923. Crustacea: Part VII Mysidacea. *Brit. Antarc. (Terra Nova) Exped. 1910. Nat. Hist. Rpts. Zool.* III (10): 273–304. British Museum (Natural History), London.

——— 1924. Crustacea: Part VIII Euphausiacea. *Brit. Antarc. (Terra Nova) Exped. 1910. Nat. Hist. Rpts. Zool.* VIII (1): 1–36.

——— 1936*a*. Mysidacea and Euphausiacea. *Great Barrier Reef Expedition, 1928–29, Scientific Reports.* Vol. 5, pt. 4, pp. 143–176. British Museum (Natural History), London.

——— 1936*b*. Occurrence and seasonal distribution of the Mysidacea and Euphausiacea. *Great Barrier Reef Expedition, 1928–29, Scientific Reports.* Vol. 2, pt. 8, pp. 278–289. British Museum (Natural History), London.

THOMSON, G. M. 1900. On some New Zealand Schizopoda. *Linn. Soc. London, Jour.* 27: 482–486.

——— 1913. The natural history of Otago Harbour and the adjacent sea, together with a record of the researches carried on at the Portobello Marine Fish Hatchery. *New Zeal. Inst., Trans. and Proc.* 45: 225–251.

Three New Copepods from Brackish-Water Lakes of Japan

TAKASHI ITO[1]

THE PRESENT PAPER deals with three new copepods found in brackish-water lakes of Japan. Two of them were obtained from the brackish fish-culture ponds along the western coast of Ise Bay, Mie Prefecture. The third specimen was sent by Professor Kikuya Mashiko of Kanazawa University and was collected from a small brackish-water lake in Hegura Island, one of the isolated islands in the Sea of Japan.

I wish to acknowledge my indebtedness to Professor Yaichiro Okada who kindly afforded me the facilities for studying the specimens which I have described in the present paper; to Dr. Masuzo Ueno, Otsu Hydrobiological Station of Kyoto University for his valuable advice; and to Professor Kikuya Mashiko of Kanazawa University who sent me the material of *Halicyclops japonicus*.

Acartia iseana n. sp.

Fig. 1

FEMALE: Length 0.955 mm., not including furcal setae.

Head distinctly separated from first thoracic segment. Rostral filaments present (Fig. 1*c*). Fourth thoracic segment completely fused with fifth. Lateral angle of last thoracic segment rounded, furnished with 4 spinules on either side. Genital segment not laterally dilated, about as long as other two abdominal segments combined, second segment about twice as long as anal segment. First two abdominal segments each with 6 spinules along distal margin of dorsal surface.

Furcal rami about 2 times as long as wide; inner margin with a few hairs. First antenna of 17 segments, when reflexed scarcely reaching end of anterior division of body.

Legs 1–4 with formula 3,2/3,2/3,2/3,2. Leg 5 with basal segment longer than wide; outer seta relatively short, shorter than terminal spine. Exopodite unsegmented, in form of a stout spine with rounded protuberance on ventral side of base; terminal spine nearly straight, about 3 times as long as basal segment, armed distally with stout spinules on either side. (Fig. 1*b*, *i*.)

MALE: Length 0.880 mm. Abdomen relatively longer than in female, and consisting of 5 segments, segment 4 well defined, but small. Furcal rami shorter than in female, 1.3 times as long as wide.

Leg 5: Right leg; basal segment longer than wide (about 2:1); lengths of basal segment and exopodites 1 and 2, 27:35:30 (μ); inner margin of exopodite 1 smooth, but with row of fine hairs; inner lobe of exopodite 2 very prominent, longer than wide, bifurcate at top; exopodite 3 very narrow at base, curved, without spine on outer margin, but with a spine on inner edge. Left leg; lengths of segments, 35:30:41 (μ); exopodite 2 elongate, more than 4 times as long as wide, bearing a small spine on top, with a few hairs on inner margin distally. (Fig. 1*j*.)

LOCALITY: Brackish-water fish ponds on coastal regions of Tsu and Matsusaka Cities, Mie Prefecture, middle Japan.

HOLOTYPE: Female, and allotype male. Taken from a mullet pond in Yonezu, Tsu City, Mie Prefecture. The type is deposited in the Faculty of Fisheries Collection, Prefectural University of Mie.

VARIATION IN BODY LENGTH: Female 0.856–1.054 mm., male 0.868–0.905 mm.

REMARKS: I found this species in six brack-

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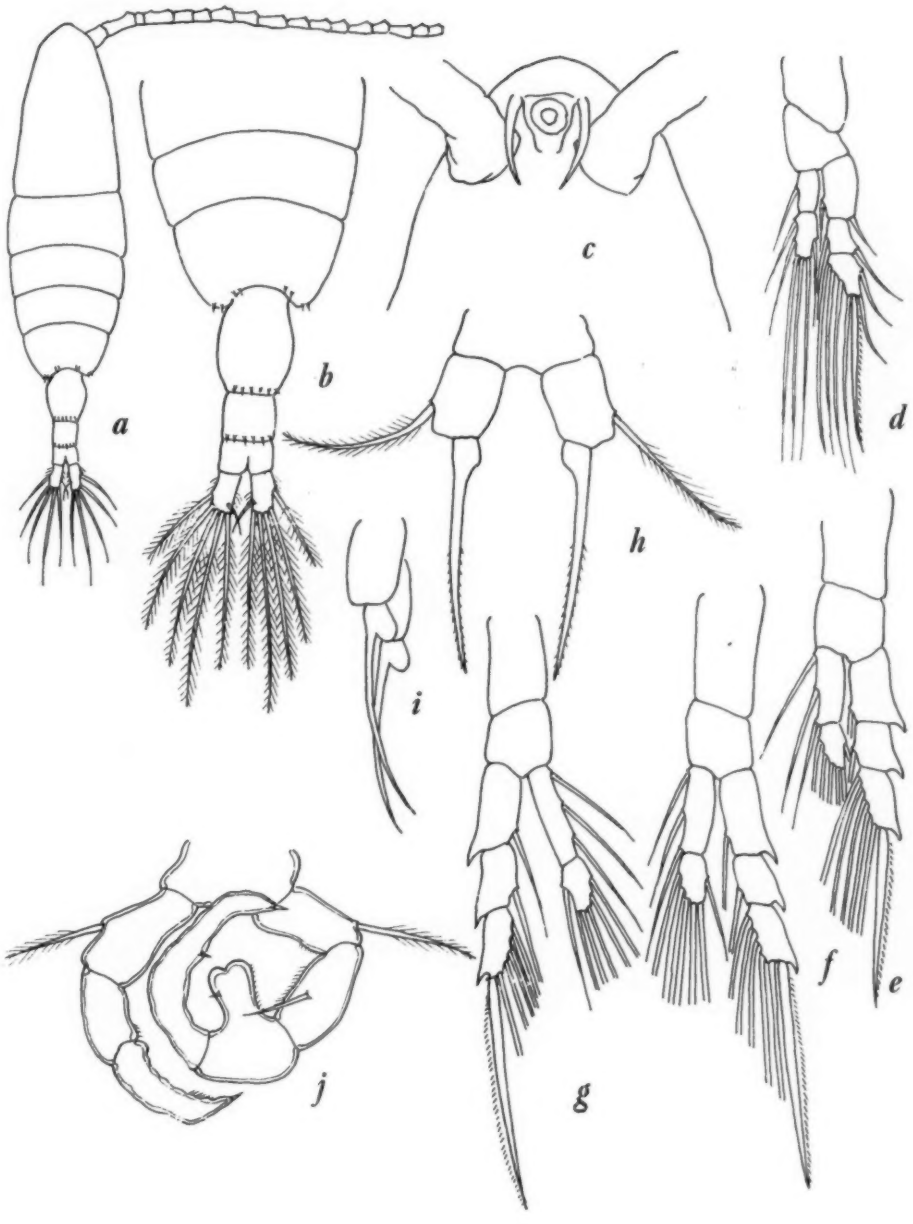

FIG. 1. *Acartia iseana* n. sp.: *a*, Dorsal aspect of female; *b*, abdomen and furca (dorsal); *c*, rostrum; *d–g*, legs 1–4; *h*, *i*, leg 5 of female, dorsal and lateral; *j*, leg 5 of male.

ish-water ponds on the coast regions of Yonezu, Tsu City, of Karasu-machi and of Matsusaka City, Mie Prefecture. Usually, this species is in company with other brackish-water forms, *Sinocalanus tenellus* (Kikuchi), *Pseudodiaptomus inopinus* Burckhardt, and *Brachionus plicatilis* O. F. Müller. The chlorinity of the ponds in which the species is distributed, ranges from 5.560 to 12.928 parts per thousand.

Acartia iseana is allied to a marine form, *Acartia bifilosa* Giesbrecht, but it is distinguishable from *bifilosa* by the absence of the fine hairs on the dorsal surface of the abdomen and by the structures of leg 5 of both sexes.

Acartia tsuensis n. sp.
Fig. 2

FEMALE: Length 0.943 mm., not including furcal setae.

Head separated from first thoracic segment. Rostral filaments present, more slender than in *A. iseana*. Last two thoracic segments fused. Lateral angle of last thoracic segment rounded, with 6 spinules on either side. Genital segment scarcely longer than other two abdominal segments combined. First two abdominal segments each with 6 spinules along distal margins of dorsal surface. Furcal rami rather shorter than that of the former species, 1.5 times as long as wide.

First antenna of 17 segments, when reflexed extending beyond end of anterior division of body and reaching to middle portion of genital segment.

Legs 1–4 with formula 3,2/3,2/3,2/3,2. Leg 5 with basal segment longer than wide, outer seta rather slender and long. Exopodite unsegmented, proximal portion wider than distal spine, about 2 times as long as wide, bearing well-developed, pointed process on outer edge; terminal spine curved inwards midway, without spinules on either side. (Fig. 2*b*.)

MALE: Length 0.843 mm. *Leg 5:* Right leg; basal segment longer than wide (about 2:1); lengths of basal segment and exopodite 1 and 2, 39:42:39 (μ); inner margin of exopodite 1 smooth; inner lobe of exopodite 2 very prominent, about as long as wide, its top not bifurcate; exopodite 3 very narrow at base, curved, without spines on outer margin, but with a spine on inner edge as in *A. iseana*. Left leg; lengths of basal segment and exopodite 1 and 2, 46:31:26 (μ); basal segment rather slender, about 2 times as long as wide; exopodite 1 very simple and smooth; exopodite 2 consisting of 2 portions, proximal protuberance bearing a slender spine on inner margin and narrower distal portion with small spine on top and subapical small process. (Fig. 2*i*.)

LOCALITY: Twelve brackish-water fish ponds in which the mullet, *Mugil cephalus* L. is cultured, on coasts of Kumozu, Tsukaigan, and Heta regions in Tsu City, Mie Prefecture, middle Japan.

HOLOTYPE: Female, and allotype male. Taken from a brackish-water fish pond in Heta of Tsu City, Mie Prefecture. The type is preserved in the Faculty of Fisheries Collection, Prefectural University of Mie.

VARIATION IN BODY LENGTH: Female 0.893–0.992 mm., male 0.818–0.868 mm.

REMARKS: This species is found in company with other brackish-water plankton animals, *Sinocalanus tenellus* (Kikuchi), *Pseudodiaptomus inopinus* Burckhardt, *Neomysis japonica* (Nakazawa), and *Brachionus plicatilis* O. F. Müller in most cases, but not accompanied by *Acartia iseana*. The chlorinity of these ponds ranges from 6.696 to 7.768 parts per thousand.

A. tsuensis is allied to *A. iseana* but it is distinguishable from the latter as follows:

Furcal rami 2 times as long as wide; exopodite of leg 5 in female bearing a rounded lobe at base of terminal spine; inner prominence of exopodite 2 of right leg 5 in male bifurcate..... *Acartia iseana*

Furcal rami 1.5 times as long as wide; exopodite of leg 5 in female with a pointed process; inner prominence of right leg 5 in male rounded..... *Acartia tsuensis*

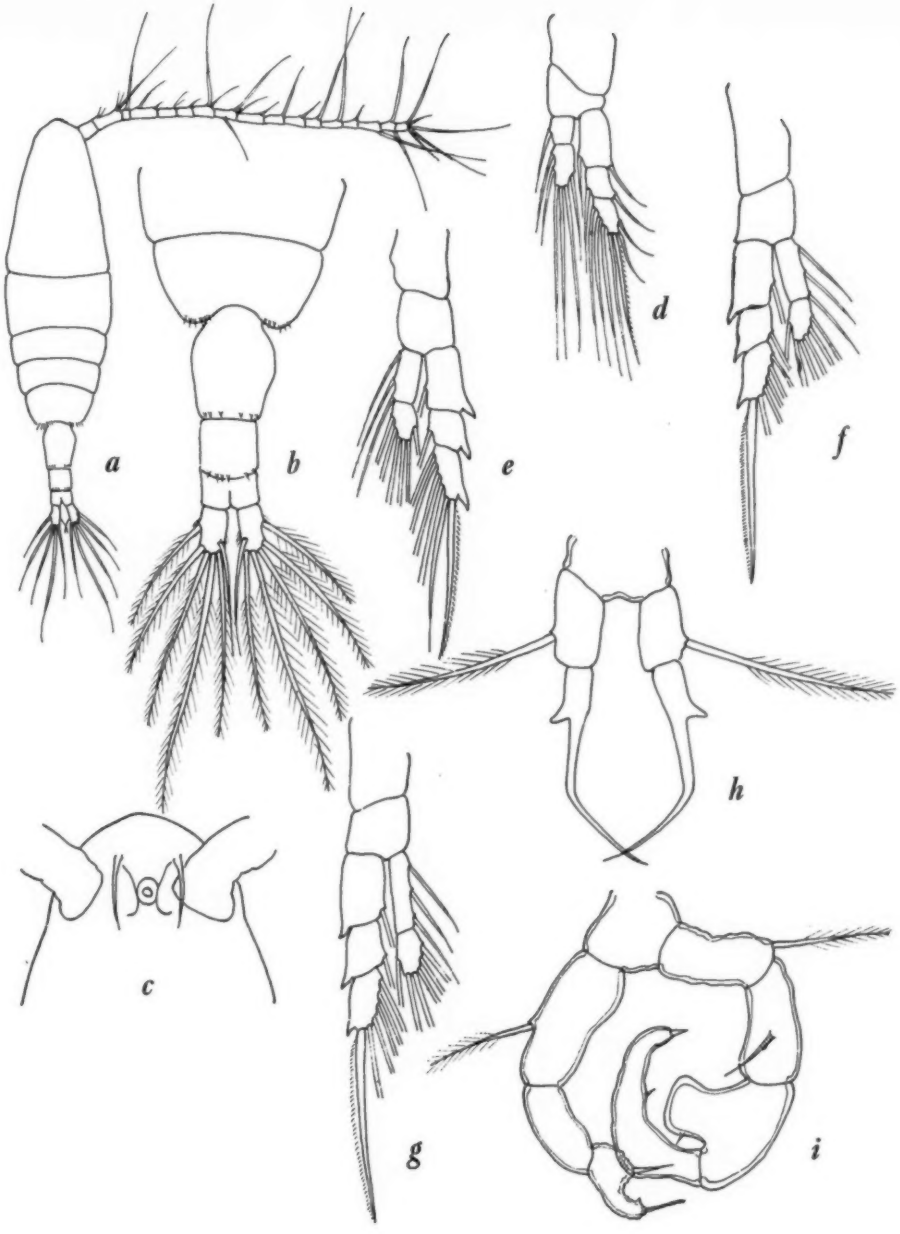

FIG. 2. *Acartia tsuensis* n. sp.: *a*, Dorsal aspect of female; *b*, abdomen and furca (dorsal); *c*, rostrum; *d–g*, legs 1–4; *h*, leg 5 of female; *i*, leg 5 of male.

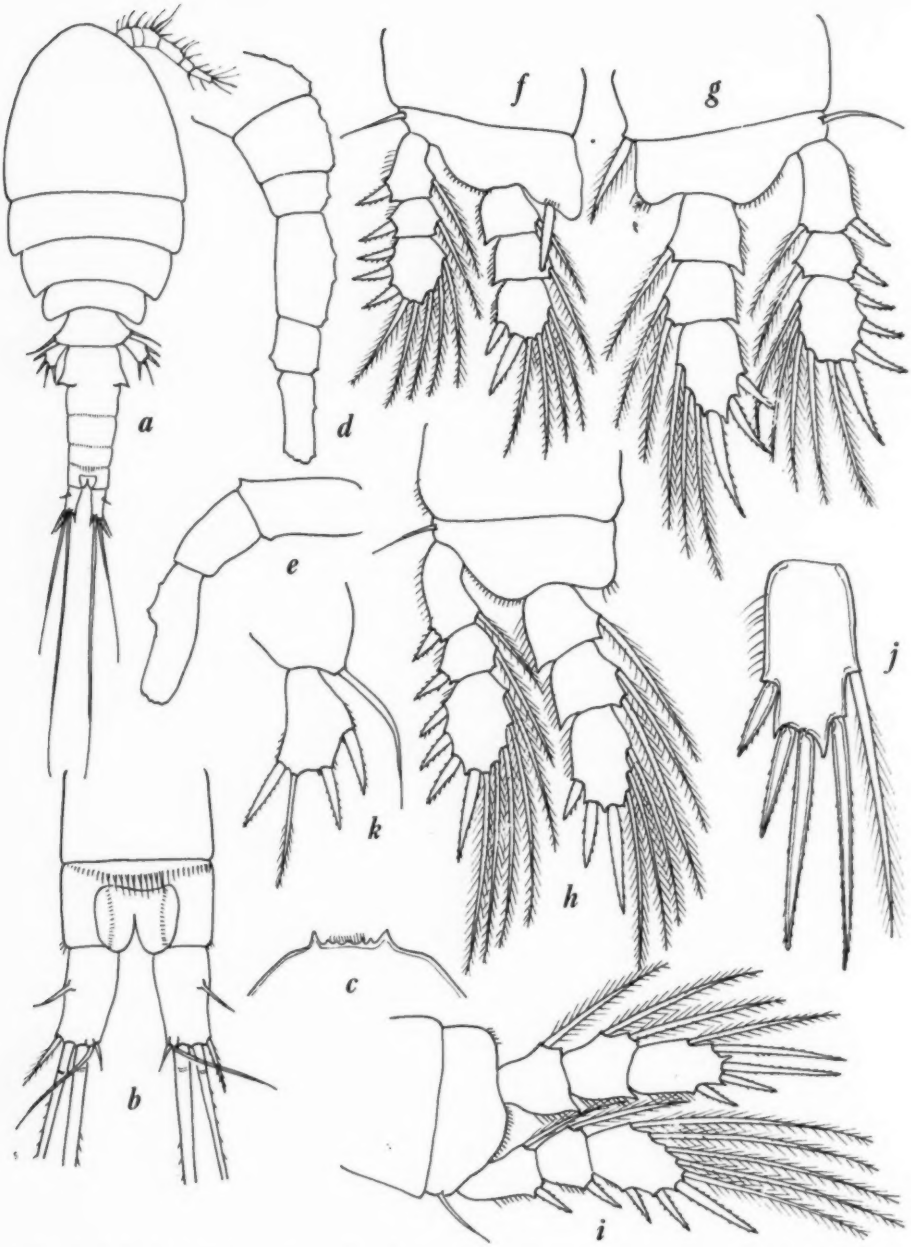

FIG. 3. *Halicyclops japonicus* n. sp.: *a*, Dorsal aspect of female; *b*, abdomen and furca (dorsal); *c*, upper lip; *d*, *e*, first and second antennae; *f–i*, legs 1–4; *j*, endopodite 3 of leg 4, *k*, leg 5.

Halicyclops japonicus n. sp.
Fig. 3

FEMALE: Length 0.66 mm., not including furcal setae. Body somewhat flattened, with distinct nauplius eye.

Upper lip rather narrow, with about 7 small, blunt teeth (Fig. 3*c*). First three abdominal segments bearing a row of spinules along posterior end of dorsal surface, middle spinules of the third segment especially well developed. Genital segment sharply produced towards side at middle on either side (Fig. 3*a*).

Furcal rami relatively long (38 μ), nearly twice as long as wide (1.9:1); lateral seta inserted at about middle of furcal rami, somewhat dorsal in position. Lengths of furcal setae as follows (from inner to outer and dorsal): 13:359:184:23:38 (μ). Inner furcal seta very short and small, 0.6 as long as outer (13:23 μ); outer seta shorter than furcal ramus; dorsal seta relatively long, much longer than the outer, arising from small protuberance; inner median seta about twice as long as the outer median seta. (Figs. 3*a*, *b*.)

First antenna very short, consisting of 6 segments, reaching to middle of cephalothorax, relative length of each segment as shown in Fig. 3*d*. Second antenna of 3 segments (Fig. 3*e*).

Legs 1–4 with formula 3,3/3,3/3,3/3,3; spine-formula in exopodite, 3,4,4,3; seta-formula in exopodite, 5,5,5,5; spine-formula in endopodite, 2,3,3,4; seta-formula in endopodite, 4,3,3,1. (Figs. 3*f–j*.) Endopodite 2 of leg 1 with an inner seta, of legs 2–4 with 2 inner setae. Leg 4 with endopodite 3 rather slender, about twice as long as wide (1.9:1), terminal spines unequal in length, inner spine 1.8 times as long as outer (45:25 μ); outer marginal seta replaced by stout spine, 15 μ in length; distal inner seta also a long, slender spine, 45 μ in length; but proximal inner seta of usual form. (Fig. 3*i*, *j*.) Connecting plate of leg 4 very simple and smooth, without special appendage.

Leg 5 with segment 1 fused with last thoracic segment, with one slender seta; segment 2 very narrow at base, rather wide at apex, bearing 3 short spines and one slender seta, each side of distal portion with several denticules. (Fig. 3*k*.)

MALE: Unknown.

LOCALITY: Ryujin-ike (brackish-water lake) on Hegura Island, Japan Sea.

HOLOTYPE: Female, is deposited in the collection of the Faculty of Fisheries, Prefectural University of Mie.

REMARKS: I found this new species in the plankton material collected by Professor Kikuya Mashiko of the Biological Institute, Kanazawa University, 3–VIII–1948, from a brackish-water lake, Ryujin-ike on Hegura-jima, Ishikawa Prefecture. The species was accompanied by another brackish-water copepod, *Paracyclopina nana* Smirnov. According to Mashiko (1950), the chlorinity of the water of the lake was 5.730 parts per thousand.

Halicyclops japonicus is allied to *Halicyclops thermophilus* Kiefer, which was described by Kiefer (1929, 1936) from a salt spring in Koeripan, Java, and which has also been reported by Lindberg (1952), from a limestone cave in Aven Vatonosifitsy, Madagascar. *H. japonicus* is distinguished from *thermophilus* by the more slender furcal rami, by the usually armed proximal inner seta of endopodite 3 of leg 4 and by the more distal location of the lateral seta on the furcal rami.

REFERENCES

KIEFER, F. 1929. Neue Ruderfusskrebse von der Sunda-Inseln. *Zool. Anz.* 84: 46–49.

——— 1936. Freilebende Süss- und Salzwassercopepoden von der Insel Haiti. Mit einer Revision der Gattung *Halicyclops* Norman. *Arch. f. Hydrobiol.* 30: 263–317.

LINDBERG, K. 1952. Cyclopides (Crustaces Copepodes) de Madagascar. *Inst. Sci. de Madagascar, Mem.* Ser. A, 7(1): 53–67.

MASHIKO, K. 1950. A brief note on the inland waters of Hegura-jima, an isolated islet in the Sea of Japan. *Jap. Jour. Limnol.* 15 (1–2): 25–29. [In Japanese.]

NEWS NOTES

Change in Editor-in-Chief

Upon the completion of volume 10 of *Pacific Science* L. D. Tuthill relinquishes the position of Editor-in-Chief. O. A. Bushnell assumes the duties of the position. Hereafter, address correspondence concerning manuscripts to Dr. Bushnell.

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